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UNIVERSITY OF ALBERTA

INFORMATION PROCESSING AND DEAFNESS: AN EXPLORATORY STUDY

by

EVELYN JUST

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

SPRING, 1992

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April 16, 1992

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The undersigned certify that they have have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled INFORMATION PROCESSING AND DEAFNESS: AN EXPLORATORY STUDY submitted by EVELYN JUST in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

in

EDUCATIONAL PSYCHOLOGY

....
Co-Supervisor L. Wilgosh

Fern Snart
....
Co-Supervisor F. Snart

....
J. D. Schein

....
J. Goldberg

....
H. Islot

....
C. Yewchuk

....
External Examiner
D. S. Martin
Gallaudet University

Date. April 16, 1992

DEDICATION

To Gabe, David and Megan with thanks for your support, patience and love.

ABSTRACT

Subjects within the present study consisted of 44 students aged 12 to 18 years who used sign language for communication purposes. The focus of the study was the relationship between the reading achievement of these students and their utilization of learning processes as measured by their performance on crossmodal and intramodal, and spatial and temporal tasks, and on phonetic encoding measures and rehearsal.

Jarman's (1975) crossmodal and intramodal tasks were used to measure auditory-visual processing ability. Spatial-temporal processing was examined using a computer program developed to assess this ability. Phonetic encoding was examined using phonetically confusable and non-confusable letter strings, replicating studies of Shankweiler and Liberman (1979) and Bisanz, Das and Mancini (1984). Scores obtained by students on the Stanford Achievement Test (Hearing Impaired Edition) (1982) completed yearly by each student served as a measure of academic performance. The results were analyzed using correlational statistics, a discriminant function analysis and cluster analysis.

A consistent pattern of learning processes could not be discerned through use of the test measures. Shankweiler-derived and Jarman tasks were able to discriminate clusters of good, average and poor academic performers. Age and degree of hearing loss were found to impact on academic ability.

The deaf subjects in the present study were noted to have strategies available to aid their recall, but it was postulated they were insufficiently motivated to use these, or were unaware of the benefits of their use.

Further research using a larger population, and including students trained both orally and through a Total Communication approach and over a larger age range, is suggested in order to determine whether patterns of learning styles can be discerned. The identification of such patterns may have direct impact on learning and teaching for deaf students.

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INTRODUCTION

The large majority of deaf persons experience considerable difficulty in developing competency in the areas of language, speech and reading (Conrad, 1979; Di Francesca, 1972; Furth, 1966; Jensema, 1975; Kohl, 1966; Lillo-Martin, Hanson, & Smith, 1990; Moores, 1982; Quigley & Kretschmer, 1982; Rodda, 1970; Vernon, 1978; Wrightstone, Aronow, & Moskowitz, 1963). The problem is so great it is estimated that for 93 percent of deaf students in the United States age 16 years and older, 30 percent are functionally illiterate, 60 percent have a grade level achievement of 5.3 or below and only 5 percent achieve a tenth grade level or better (Quigley & Kretschmer, 1982). (Although no mention is made of the other 7 %, it is assumed this figure includes those deaf individuals who experience little difficulty in school and for whom linguistic competence is easily developed).

This low reading ability is not solely an English language phenomenon. 'Very low' reading abilities are also reported by researchers in Sweden where graduates from schools for the deaf barely achieve a reading level at the 4th grade, and in Denmark where deaf school graduates are described as basically being unable to read (Conrad, 1979).

Rozin and Gleitman (1977) reported that where non-orthographic pictorial languages such as Chinese are used, deaf students do learn to read. Fok, Bellugi, van Hoek, and Klima (1990) have attributed this to the visual-spatial script of the Chinese language. It is interesting to note that similar results have been reported with reading disabled-English speaking children. For example, Makita (1968) reported that Japanese Kana, a form of syllabic script, is readily mastered by hearing first graders who have had no systematic training in phonetic skills. In addition Rozin, Poritsky, and Sotsky (1977) reported reading disabled children have less difficulty mastering an orthography in which each word is represented by a different symbol than in mastering an alphabetic script which requires phonetic skills.

To date no similar research has been reported examining deaf and learning disabled children. However the general trend seems to indicate these two populations, reading disabled and deaf, although quite distinct in auditory capability, manifest similarly general trends in their abilities with phonetic and visual symbolic language.

Research comparing deaf students using sign language with oral deaf students has indicated those using a visual sign language system achieve somewhat better in school (Conrad, 1979;

Schlesinger & Meadows, 1972; Moores, 1982; Quigley & Kretschmer, 1982). This visual language form may lead to the measurably improved academic success. However, it may also be that those deaf children immersed in sign language from birth are afforded a greater opportunity to develop and use linguistic skills. A sign language environment in some way parallels the auditory language environment of a normally hearing child. The deaf child, growing up in a strictly auditory environment, on the other hand, may only be able to make use of that linguistic information which can be abstracted through the faulty auditory mechanism and through other incidental and non-systematic cues. In fact, research comparing deaf children of deaf parents with deaf children of hearing parents has indicated the deaf child of deaf parents performs better on academic language tasks than does the deaf child of hearing parents (Conrad, 1979; Ballow & Brill, 1975). This result remains constant even when the effect of intelligence is partialed out (Jensema & Trybus, 1978). However, Conrad and Weiskrantz (1981) have suggested unintentional sampling bias, wherein mainstreamed oral deaf students were not included as part of the sample selection, may account for these, and similarly reported differences in performance.

With hearing individuals, a positive relationship is reported to exist between crossmodal ability and reading proficiency. When reading, the reader places the semantic representation of the printed form into an auditorally recognizable phonetic representation. This requires receiving information through one sensory modality - vision - and recoding the information using another sense - hearing - in order that meaning be ascribed to the information received. This joint use of two sensory systems for input and output is called **crossmodal ability.** The use of one sensory system for the reception and expression of information (such as listening and speaking) is termed **intramodal ability.**

Jarman (1975) devised a unique method of determining hearing subjects' ability to perform **crossmodal** and **intramodal** tasks using the auditory and visual modalities. The Jarman technique is of special interest to the present investigation since it is not linguistically based. As such it may lend itself particularly well to use with deaf subjects since it does not require, but rather bypasses the particular language deficit of the deaf population. This somewhat unique approach has been adopted by the present investigator. For the first time, an experimental approach has been utilized to determine auditory-visual learning ability which does not emphasize language skills. Although severely to profoundly hearing impaired, the majority of the deaf population have some useable hearing which may allow Jarman's auditory tasks, as well as their visual counterparts, to be employed.

Considerable research has addressed the importance of temporal processing and its relationship to academic success (Jarman, 1975; Myklebust, 1964). Research conducted by Blair (1957), Conrad (1979), and Hermelin and O'Connor (1964) has reported the deaf as a group to be more proficient at processing information in a spatial manner whereas their hearing counterparts are superior in temporal processing. It must be emphasized that these results should not be taken to indicate all deaf individuals exclusively process information spatially, since these studies generally ignore individual differences. For example, research does not show if deaf individuals who process information temporally are more proficient, less proficient or similar on academic performance tasks to deaf students who process spatially. In addition, research is not reported comparing the functioning of hearing subjects who are temporal processors with hearing spatial processors. Nor does the literature compare hearing with deaf peers who both process spatially. Thus the present study attempted to compare the academic performance of deaf temporal processors with deaf spatial processors.

Numerous studies have examined the relationship between deafness, and academic achievement on language tasks (Conrad, 1979; Jensema, 1975; Jensema & Trybus, 1978; Kusche, Greenberg, & Garfield, 1983; Myklebust, 1964; Vernon & Koh, 1970; Wolk

Allen, 1984). In general, these studies have reported that deafness negatively impacts on tasks which are linguistically based. This negative impact is reported to be lessened in the presence of phonetic coding. For example, Conrad (1979), in extensive research with British deaf school children, found the presence of phonetic encoding to be predictive of the ability to internally manipulate language.

For deaf students who use sign, the manipulation of language may occur using the visual-graphic symbols of letters or through the dactylic handshapes representing the same visually presented letter forms. Shankweiler and Liberman (1979), using phonetically confusable and non-confusable letter strings, reported phonetic encoding ability to be directly related to reading ability. Bisanz, Das, and Mancini (1984) took this a step further and reported that although phonological encoding of language is important for reading, the use of **rehearsal** strategies seems to be an important factor underlying competent performance in reading. Although research has been conducted investigating the phonetic coding ability of deaf signers utilizing graphic letter symbols, no research is reported to date which compares their phonetic encoding ability using graphemic and dactylic (fingerspelled) symbols. Further, research is not reported with deaf individuals wherein rehearsal has been suppressed auditorally and manually in order to determine whether they may use a method of rehearsal which relies on their reported spatial preference. The relationship between method of recall and reading ability, and rehearsal and reading ability are areas requiring investigation.

In summary, the present study examined the relationship between reading achievement of deaf students, aged 12 to 18 years, and their utilization of learning processes as measured by their performance on crossmodal and intramodal, and spatial and temporal tasks and on phonetic encoding measures and rehearsal. The overall objective of the study was to increase the available body of knowledge on how deaf individuals learn, thus contributing to improving their academic proficiency.

II. REVIEW OF THE LITERATURE

Deafness, Reading and Language

It is difficult to rigorously and unequivocally define hearing impairment. At a superficial level, hearing impairment presents itself as a relatively homogeneous disability in as much as it is characterized by an inability to detect or process auditory stimuli. Such a view is extremely misleading and belies the complexity and far reaching ramifications of the disorder. A variety of educational, social, cognitive and vocational handicaps are associated with different kinds and degrees of hearing loss.

Complicating any discussion of hearing impairment is that this category subsumes two rather distinct populations, the deaf and the hard of hearing. These two groups are qualitatively different from one another both in nature of the handicap and in the kind of educational interventions that can be successfully applied (Davis & Silverman, 1978).

Hearing impairment exists on a continuum and there is no established boundary line separating hard of hearing and deaf. For example, there are no acceptable criteria delineating the degree of impairment in processing linguistic information that is required to be classified as deaf or hard of hearing. Schein and Delk (1974) stated that any definition of deafness is arbitrary and reflective of individual theoretical and philosophical perspectives.

General definitions of the terms 'deaf' and 'hard of hearing' have been proposed over the years. The most recent reformulation of these definitions was developed by an Ad Hoc Committee on Definition of Deafness and Hard of Hearing appointed by the Conference of Executives of the American Schools for the Deaf and chaired by Robert Frisina (1974). Hard of hearing was defined as "a disability in hearing where, generally with the use of amplification, there is sufficient residual hearing to enable successful processing of linguistic information through audition" (Frisina, 1974, p. 5). For the hard of hearing, the auditory channel, albeit impaired, can serve as the primary receptor of language with the visual channel assuming a secondary role.

This committee defined deafness as "a disability in hearing to an extent which precludes the hearing and understanding of speech either with or without amplification" (Frisina, 1974, p. 4). For deaf individuals, the auditory channel is sufficiently damaged to preclude auditory development and comprehension of speech and language. Thus, the visual channel serves as the primary receptive channel for receiving information through speechreading, gesturing, signing and fingerspelling (Ross, 1977).

Where hearing subjects utilize audition for reception of language, the deaf are assumed to use a visual, an auditory, and to a lesser extent, a kinesthetic system for language reception. For hearing individuals, language expression is primarily an oral process. For deaf individuals language is expressed by way of visual-kinesthetic and,to a lesser extent, through oral means. Even 'inner language', described by Myklebust (1964) as the relationship between experience and symbol usage, is postulated to develop through different sensory modalities for each group: audition for hearing and vision for deaf.

For normally hearing individuals, language is primarily an auditory-verbal process, which follows a hierarchy of auditory reception (listening), verbal expression (speaking), visual reception (reading) and graphic expression (writing). For the child who is born deaf, language is largely inaccessible at the first step of this hierarchy. Since a considerable portion of language cannot be visually discerned, reliance primarily on a visual system may interfere with three distinct, but interactive, realms: receptive or input functions, integrative functions, and expressive, or output functions thus exacerbating the problem of language facility, social interactions, and so on (Mancini, 1991).

Additionally, other auditory/oral sources which impact on the language development of the hearing child (radio, cartoons, the language of peer interaction, and the like), are largely inaccessible to the profoundly deaf child, thus markedly reducing and impacting upon background information, social trends and general enrichment. Therefore, in general, the greater the degree of hearing impairment, the greater will be the impact on language learning. As a result, deafness is generally associated with academic deficits especially when these tasks are linguistically based.

This academic delay may be 2 to 5 years, or even greater, depending on the age of the child when testing occurs. For example, Gentile and Di Francesca (1969), reporting on a sample of thousands of school aged deaf children, stated that by approximately 8 years of age the deaf child demonstrates a grade 2 reading and arithmetic proficiency. However, the sobering reflection is that by age 17, academic proficiency is reflected by an academic standing of Grade 4 in reading and Grade 6 in arithmetic. Similar findings have been reported by Conrad (1977) utilizing groups of British school aged children, and by Allen, White and Karchmer (1986), Di Francesca (1972), Trybus and Karchmer (1977), Wolk and Allen (1984), and Wrightstone, Aronow, and Moskowitz (1963) with groups of American and Canadian students.

It is interesting to note that similar discrepancies have been reported within the hearing population when average readers are compared with reading disabled children (Calfee, Lindamood, & Lindamood, 1973).

One of the criteria for classification of severe reading disability within the hearing population is a delay in reading ability of greater than two years based on age and grade expectancy. Within the context of a reading delay, therefore, the performance of the deaf, as a group, appears to be similar to that of a severely reading disabled population.

Measurements of reading ability in the deaf population are based on norms derived using hearing subjects, the goal being functional literacy. Gray (1956) used grade 4 as the acceptable threshold for functional literacy. Furth (1966) suggested grade 5 as the minimum requirement. As well, grade 6 is often cited as the level of reading skill required to read the newspaper. Bullock (1975) defined illiteracy as a reading level of less than grade 2, a semi-literate reading level as between grade 2 and 4, and ability to read complex material requiring a reading level of grade 10 and above. Depending on the criteria used, therefore, a varying proportion of the deaf population could be termed illiterate.

Researchers and educators from the area of deafness have voiced a unified concern for deaf students' lack of measureable improvement in English language proficiency. Exemplary to this, Moores (1982) decried this situation, stating that:

> For the profoundly deaf, language is not a facilitating device for the acquisition of knowledge. Rather it is a barrier standing between them and the full realization of their academic, intellectual and social potentials. Although deafness itself has no effect on intellectual potential, the deafness will lead to impoverished communication skills that themselves may limit development severely, unless the children are provided compensatory tools. (p.3)

The use of sign language is one such compensatory tool which is reported by some researchers to have a positive effect on the development of communication skills and thus on language ability (Bellugi & Klima, 1975; Bornstein, 1973; 1974; Karchmer, Trybus, & Piquine, 1978; Moores, 1982). Sign language is the visual representation of language through hand shapes and movement patterns (fingerspelling and sign). It is a systematic visual language form which may exist as a language completely on its own or follow the syntax of another language. American Sign Language (ASL) is an example of the former while Signed English is an example of the latter (Bergman, 1972; Bornstein, 1973; 1974; Wilbur, 1979).

ASL is a visual-gestural language system having a syntax, morphology and word order distinct from English. It is the natural sign language system of the deaf in North America. It consists of fingerspelling, a different hand shape for each letter of the alphabet and a plethora of signs differing in terms of location, hand configuration and movement pattern (Bellugi & Klima, 1975).

English-based sign language systems have been created by educators to parallel the syntax, morphology and word order of English in order to aid deaf children in developing and understanding English language. The most enduring of these (Signed English, Manual English) have borrowed meaning-based signs from ASL and added indicators for verb tense, pronouns, plurals, and the like to produce a sign system that parallels English.

Various researchers have reported a high correlation between sign language use and academic success (Conrad, 1979; Jensema & Trybus, 1978; Kohl, 1966; Meadows, 1968; Moores, 1982; Quigley & Kretschmer, 1982; Sisco & Anderson, 1980; Vernon & Kohl, 1970). Other researchers (Meadows, 1968; Zwiebel & Mertens, 1985a) have also reported that those who perform best on reading tasks are hereditarily deafened students of deaf parents, raised using sign language in their daily communication.

Cause of deafness has also been reported to affect academic ability. Conrad (1979), and Trybus and Karchmer (1977) have reported a variety of factors including age of onset of deafness, sex, ethnicity, degree of hearing loss, presence of additional handicaps, age of beginning school and parental deafness to bear a relationship to reading achievement. However, the availability of sign communication from an early age is present for only those ten percent of children born of deaf parents and potentially for the additional ten percent having other deaf family members (Schein, 1989). Deaf children of deaf parents who learn ASL as their first language are termed bilingual, using ASL in their social milieu and an English based sign system for educational purposes.

While sign language is described as a compensatory tool, it must be noted that other variables may significantly impact on the linguistic development of the deaf child. For the deaf child of deaf parents, the mutual deafness may itself afford greater acceptance than may occur with hearing parents of deaf children. This may result in more nurturing child rearing and thus impact on the child's overall development (Schlesinger & Meadows, 1972; Karchmer, Trybus & Piquine, 1978; Sisco & Anderson, 1980; Vernon & Kohl, 1970).

Kusche, Greenberg, and Garfield (1983) have postulated a genetic etiology for the superior non-verbal performance of genetically deafened children, both of deaf and hearing parents. Conrad and Weiskrantz (1981) suggested unintentional sampling bias may have skewed the samples on which this, and the Karchmer et al. (1978) and Vernon and Kohl (1970) studies were based. However, they did not refute the able performance of this genetically deafened group.

Generally, by the time a normally hearing child is 2 1/2 years of age, he or she has internalized a complete language system on which to build future language learning. Without the use of a visual language base in the home, more than 80% of deaf children entering pre-school or school level programs are alinguistic. It is apparent, therefore, that for the child who is born deaf, delayed language development may significantly impact on the development of reading skills.

Language deficit is also reported to affect other non-linguistic areas of functioning. Children with hearing impairments are specifically delayed on tests involving abstract figural reasoning and verbal reasoning although no identifiable delay in reasoning at the concrete level has been reported (Furth, 1966). Rosenstein (1961) attributed this deficit to language deficiency as no differences in abstract reasoning were noted between deaf and hearing subjects when tasks were within the language level of the deaf child. Zwiebel and Mertens (1985a) similarily reported deaf subjects to utilize abstract thinking at a level commensurate with their hearing peers, although they were more reliant on memory skills than were their hearing counterparts.

The language delay of deaf learners is postulated as a consequence of two main groups of causes which envelop a variety of factors. These include **global** causes and **specific** causes. **Global** causes include experiential deficits (Furth, 1973), impoverished social and intellectual development (Furth, 1966), auditory deprivation (Myklebust, 1964) and atypical hemispheric lateralization (Kelly & Thomlinson-Keasey, 1978; Kusche, 1985; Rodda, Buranyi, Cumming, & Muendel-Atherstone, 1985). **Specific** causes include auditory-temporal processing deficits (Das, 1983), paucity of the use of a speech-based code (Dodd, 1980; Hanson, 1982), memory deficits (Hanson, 1982, 1985;) and inefficient use of strategies (Hanson, 1985; Kusche, 1985; Liben, 1985). These can be broadly classified within an information processing perspective. The present study focuses on these specific causes of language delay. Further, it is concerned with deaf students for whom sign language has formed an integral part of their education.

Whereas hearing individuals are reported to exhibit a preference for processing information in an auditory-temporal manner (Das, 1983), deaf individuals are reported to exhibit a preference toward utilizing a visual-spatial processing method. As well, whereas hearing individuals are reported to rely moreso on phonetic coding (Conrad, 1964), deaf individuals, in addition to using a phonetic code (Conrad, 1964; Hanson, 1982; Locke & Locke. 1971; Wallace, 1972; Wallace & Corballis, 1973), are reported to rely on alternate means including orthographic (Wallace & Corballis, 1973), kinesthetic, (Wallace, 1972) visual (Conrad, 1979) and proprioceptive coding (Locke & Locke, 1971; Rodda & Grove, 1987). Strategy use and memory have been suggested to be important for all areas of information processing and are reported to be used to assist recall for both hearing individuals (Bisanz, Das, & Mancini, 1984) and for deaf individuals (Hanson, 1985).

In summary, research presented to date has reported the deaf to be consistently delayed in academic tasks and, in general, the greater the degree of deafness, the poorer is the academic performance. However, where compensatory strategies such as the use of sign language are employed, academic performance is generally better. For deaf individuals, a visual system of language reception and expression is hypothesized to predominate, whereas an auditory receptive method predominates for hearing individuals.

Each of these areas is reported to impact on the development of reading skills. The significance of this difference in cognitive learning style will become clearer subsequent to a review of the literature on auditory and visual style, spatial-temporal processing and phonetic coding and strategy use as they relate to deafness.

Auditory Visual Processing Deafness

As earlier noted, the hearing impaired population may be divided into two quasi-distinct groups - the hard of hearing, and the deaf - based on their preferred mode of communication: oral or manual. The deaf group predominantly use sign language for communication purposes. It has been suggested that this use of sign language contributes to the spatial processing preference exhibited by deaf individuals (Karchmer et al., 1978). As oral language and written information are temporally sequenced, it has been proposed that this marked difference between preferred method of processing and that required for reading text may significantly impact on the reading delay measured in deaf individuals.

Learning disability theorists have postulated that the majority of learning occurs through the two primary sensory channels of audition and vision and, concomitantly, learners have been divided into two broad information processing classifications based on primary cognitive/learning style: **auditory learners** and **visual learners**. The term **cognitive style** " refers to individual variations in modes of perceiving, remembering, transforming and utilizing information " (deVilliers & deVilliers, 1979, p. 247).

Both auditory and visual methods of processing information are needed to perform a variety of tasks. Where the decoding and encoding processes utilize one sensory modality, for example, audition or vision, the term **intramodal** processing, is used. Where two sensory modalities are involved, for example, the use of both audition and vision, the term **crossmodal** is applied. Listening/speaking is an example of the former, whereas reading aloud is an example of the latter.

When reading, the reader places the semantic representation of the printed form into an auditorally recognizable phonetic representation. This requires receiving information through one sensory modality - vision - and recoding the information using another sense - hearing - in order that meaning be ascribed to the information received.

In studies investigating the area of reading proficiency, the ability to integrate, associate or establish equivalence between stimuli from different sensory modalities, that is to perform crossmodally, has been shown to be related to reading ability (Jarman, 1975; Torgesen, 1975). Crossmodal auditory-visual integration has been shown to become more important as the child becomes older (Jarman, 1978). Further, research conducted with grade 3 and grade 4 hearing students (Sterritt & Rudnick, 1980) has found auditory-visual crossmodal ability to be a significant predictor of reading ability.

Jarman (1979) examined hearing seven and nine year olds'ability to process auditory and visual information within and across modalities. He concluded that information is processed independent of the mode of presentation. This conclusion is inconsistent with predictions made from the modal-specific view of sensory systems. In fact, kindergarten children studied by Sterritt and Rudnick (1980) exhibited a preference for processing auditory information temporally whereas grade one children demonstrated equal facility with handling temporal information both auditorally and visually.

Jarman has suggested that although information processing may be modality-specific at an early age, it gives way to non-modal specific processing as a result of a 'cognitive developmental shift' between 5 and 7 years of age. Other researchers (Doehring, Trites, Patel, & Fiedorowicz, 1981; Francis 1972) have indicated that a 'developmental shift' in language also occurs at about the age of seven when language begins to be processed abstractly. At about this age, the child shifts from a pre-operational to a concrete operational stage in traditional Piagetian terms (Francis, 1972). This increased cognitive processing capacity afforded by the emergence of the epilinguistic shift, movement from pre-operational to a concrete operational stage, and the ability to use the visual and auditory modalities interchangeably, enables the child to mentally coordinate various sources of information when reading. He or she can attend both to the graphemic and phonemic characteristics of words, the semantics, letter order and sound order. By this age, the child can 'decode' unfamiliar words and understand the relationship between letters and their respective sounds (Francis, 1972). Additionally, the child at this stage may be able to process information independent of the mode of input (Jarman, 1975). Doehring, Trites, Patel, & Fiedorowicz (1981) have theorized a link between neural development and a cognitive-linguistic maturational shift which occurs between early childhood (age 2 to 6) and middle childhood (age 7 to 12). This language shift is characterized by the emergence of (1) the ability to process syntactic structures epilinguistically, (2) metalinguistic awareness, (3) episodic-semantic memory organization and (4) reading acquisition (Doehring et al., 1981). In addition, the increased frequency of phonetic errors as opposed to non-phonetic errors noted by Conrad (1962; 1972) and Conrad and Rush (1964) may likewise increase as the child's attention to grapheme-phoneme correspondence increases. Jarman (1975; 1977b; 1798; 1979; 1980) reported that hearing students who are unable to process information crossmodally by approximately 10 years of age also fare poorly on reading tasks.

Zwiebel and Mertens (1985a) theorized that the measured difference in intelligence factors between hearing and deaf subjects in their study may have been the result of a lag in intellectual development. If this is the case for deaf individuals, this population may be greatly delayed in making the transition from modality specific to modality non-specific processing or tend to process information more in an intramodal than a crossmodal fashion. As with reading disabled hearing students, deaf students' ability to perform crossmodal operations may predict their ability to function on reading measures. There is a paucity of research examining the possibility of a 'developmental shift' and/or 'language shift' in the deaf. Deaf individuals may be academically delayed as a function of the delayed onset of this 'developmental' or 'language' shift.

Because of the language deficit experienced by some deaf learners, language-based tasks cannot be employed in studies to determine cognitive style with this group. Their difficulty with the tasks could in large part be attributed to their language delay and, to date, it has been impossible to partial out the degree of deficit accountable to the deafness. For this reason, a satisfactory method of measuring auditory and visual cognitive style in deaf individuals has not been available.

Following the work of Birch and his associates (Belmont, Birch & Belmont, 1968; Birch & Bitterman, 1949; 1951; Birch & Belmont, 1964; 1965 Kahn & Birch, 1969; Klapper & Birch, 1971), Jarman developed a method of measuring auditory and visual cognitive style with hearing subjects which does not rely on linguistic abilities. He presented his subjects with a series of auditorally presented tones and visually presented dots to be matched for 'same' or 'different'. Four tasks were designed, two as measures of intramodal match and two as measures of crossmodal ability.

The intramodal tasks use a primary stimulus which is matched with a second stimulus of the same type. That is, a visual dot pattern is matched with another visual dot pattern, or an auditory tone pattern is matched with a second auditory tone pattern. For the crossmodal tasks, the primary stimulus is presented in one modality while the matching stimulus is presented to the alternate modality, visual then auditory, or auditory then visual. After viewing and/or hearing the primary and comparison stimulus, the subject reports whether the two stimulus pairs are the same or different.

These tasks are performance (non-language) based and should be useful measures for determining auditory or visual cognitive style in a deaf population. The large majority of the deaf population possess some useable hearing which is measured through pure tone audiometrics. Jarman's auditory tasks also utilize a pure tone, organized in varying patterns of tone and pause. Just as the audiogram is useful for measuring hearing, so should Jarman's auditory tasks and their visual counterparts be appropriate to use with a deaf population to determine their auditory and visual processing skills.

Research conducted with hearing individuals has reported a positive correlation between performance on crossmodal tasks and reading ability (Jarman,1975, 1977, 1978, 1979, 1980; Sterritt & Rudnick, 1980). Deaf individuals who are able to process information crossmodally may also prove to be similar to their hearing peers, and be functional readers. The nature of the relationship between crossmodal ability and reading proficiency for deaf individuals thus bears investigation.

An additional area wherein the cognitive style of deaf individuals has been examined is that of spatial temporal processing. Attention will now shift to an examination of this area.

Temporal Spatial Processing and Deafness

Various researchers (Beck, Beck,& Gironella, 1977; Blair, 1957; Clark, 1990; Cumming & Rodda, 1990; Das, 1983; Hermelin & O'Connor, 1964; Olson & Furth, 1966) have examined temporal and spatial methods of processing in deaf and hearing individuals. Although the literature is divided in its results, in general deaf individuals are reported to predominantly utilize a spatial method of processing information whereas hearing individuals exhibit a preference for temporal processing.

With hearing subjects, Blank, Weider, and Bridger (1968) and Blank and Bridger (1966) found that both able and disabled readers performed equally well on spatial matching tasks whereas when the matching task was temporal, disabled readers performed less well. Various researchers have substantiated the positive relationship between temporal processing ability and reading achievement (Doehring et al., 1981; Jarman, 1975; Shankweiler & Liberman, 1979; Torgesen, 1975; Torgesen & Goldman, 1977).

O'Connor and Hermelin (1978) used photographs of faces as non-nameable items and non-word consonants-vowel-consonant (CVC) combinations as the nameable items in a study of memory skills of deaf and hearing individuals. Using a probing technique, hearing subjects recalled the CVC items better than the deaf subjects, but the deaf subjects recalled the order of the faces better than their hearing counterparts. O'Connor and Hermelin theorized recall of the nameable items to draw more on auditory memory skills and recall of the non-nameable items to rely more on visual memory ability. They concluded that it seemed unlikely that retention of temporal order was dependent on an intact auditory system (p. 341).

More recently, research (Martin, 1985) in the field of deafness has supported the conclusion that where information to be recalled is not "language bound", temporal processing occurs with deaf individuals. However, when the information is serially ordered and linguistically based, such as occurs with English language tasks, less able recall abilities are measured for these individuals.

Other researchers (Hanson, 1982; Krakow & Hanson, 1985; Wallace & Corballis, 1973) have reported the finding that deaf individuals experience greater difficulty with ordered recall than with free recall tasks. Krakow and Hanson suggested that difficulty with serial order does not interfere with ASL language learning because ASL utilizes the simultaneous production of linguistic units unlike English which depends upon word order for meaning. In support of this, Kretschmer and Kretschmer (1978) have suggested that the use of sign language, visually based, may in fact reinforce the spatial processing method which is reported to predominate for deaf individuals. However, such a difference in processing information could markedly impact on reading ability.

When comparing memory skills of deaf and hearing individuals, various researchers have used serial recall procedures (digit forward and digit backward) to measure memory span of deaf and hearing subjects. Blair (1957) reported his deaf subjects remembered visually presented digits equally well backward as forward, whereas hearing subjects were able to recall longer digits strings and also remembered better forward than backward. In the Blair study, the entire array of digits was present for a set period of time.

Other studies examining memory span of deaf subjects have used successively presented letters sequences (Hermelin & O'Connor, 1964; O'Connor & Hermelin, 1973). The 1964 study found no difference in forward or backward recall while the 1973 study found that the deaf subjects recalled better backward than forward. Regardless of overall performance with respect to psychometric results, deaf students fared more poorly than hearing students on memory span measures.

The equivalence of letters and digits in measuring memory span has not been examined to date. This gap may have been a contributing factor to the differences found when the Hermelin and O'Connor, and O'Connor and Hermelin studies were compared with the results obtained by Blair. In addition, the different methods of presenting the digits may have been a confounding variable responsible for differences obtained. In the Blair (1957) study, simultaneous presentation was used whereas in the Hermelin and O'Connor (1964) and O'Connor and Hermelin (1973) studies, successive presentation was used.

O'Connor and Hermelin (1973) used digits in a display box having 3 adjacent windows to measure the relationship between deafness, naming and temporal order. Single digits appeared one at a time in a spatial or temporal fashion.

> In any one display the spatial and temporal order of digits was incongruent, so that they never appeared in a left to right succession. For instance if the numbers occurred in a temporally successive order, for e.g. 3 9 7, the spatial order might be 9 in the right hand window, 7 in the middle one and 3 in the left hand one (p.337).

After the series was displayed well within the subject's memory span, subjects were directed to report the digits they had observed. Hearing subjects were more than four times as likely to report the temporal order as they were to report the spatial order. The deaf subjects, on the other hand, were eight times as likely to report the spatial ordering of the digits. Based on previous research showing that mode of response was irrelevant for the hearing, alternate reporting techniques were used by the deaf and hearing subjects. Hearing subjects reported the digits orally, while deaf subjects wrote their responses on paper. Since the researchers failed to counterbalance response mode, the theory that mode of response is irrelevant for deaf subjects cannot be claimed.

In the O'Connor and Hermelin (1973) study, the researchers failed to consider that a third method of responding, in addition to simply spatial and temporal responding, was available to the deaf subjects who recorded their responses on paper. This response pattern is a combination of both the above into a temporal-spatial method of responding. The deaf subjects, permitted to write their responses, could record the digits presented in a temporal fashion by recording the order in which the digits were presented, in a spatial fashion by recording the visual array of digits, or in a temporal-spatial manner utilizing a combination of the above two methods.

An example of these three response types would be that in recording the digits presented in the temporal order of 3 5 8 and the spatial order 5 in the left, 3 in the middle, 8 to the right, a subject could respond **temporally** by recording the digits 3 5 8 in succession on the paper. A **spatial** response pattern would result from the subject recording the digits as 5 3 8. A **temporal-spatial** response pattern would result from recording the digits 3 in the middle, recording the 5 in front of the digit already recorded on the paper, (5 3) and then recording the 8 at the end of the series (5 3 8). When scored, this latter response pattern would be treated as a spatial recall pattern, when in fact the method of recall was actually a combination of the two primary methods. The hearing subjects, verbally recalling each series, did not have this method of recall at their disposal. This could, in part, account for the high discrepancy between the results achieved for these two groups. If this were the case, method of recall, determined to be irrelevant for hearing subjects, could well be significant for the deaf and thus bears examination.

Beck, Beck, and Gironella (1977), using a procedure similar to O'Connor and Hermelin (1973), assessed spatial and temporal preferences of oral and sign language using deaf students and hearing peers. They were unable to support O'Connor and Hermelin's findings of a preference for spatial processing by the deaf. Das (1983) likewise used O'Connor and Hermelin's procedure with sign language using deaf students and hearing peers, but with the addition of a probed recognition condition added to the free recall response condition. Although Das was unable to confirm a spatial preference for deaf individuals or a temporal preference for hearing, on the probe recognition condition, deaf students responded better to the spatial than to the temporal probe.

In fact, a temporal-spatial response pattern could have been utilized by the deaf students in the Beck et al. (1977) and Das (1983) studies. Here, deaf students signed their responses. In so doing, they could have used visual space in signing their responses resulting in a method of responding parallel to the temporal-spatial pattern described above. Beck et al. and Das do not describe the manner in which signed responses were presented. For the hearing subjects, orally responding, only temporal or spatial response choices were available. Again, this alternate response pattern, available to deaf subjects, may have contributed to the differences reported.

In summary, research reported to date reveals that the method of recall employed by deaf and hearing individuals appears to differ. Whereas hearing individuals exhibit a preference for temporal processing, research conducted with deaf individuals presents varied results regarding their preferred processing preference. Early research (Blair, 1957; O'Connor & Hermelin, 1973) reported a spatial preference while later research (Beck, Beck, & Gironella, 1973; Das, 1983) was unable to substantiate this viewpoint.

However, in each of these studies, method of response to tasks presented may have masked a temporal-spatial response mode available only to the deaf subjects. If this combination of processing methods is utilized by some deaf subjects, these individuals may also differ in their processing of other information. For example, if their first preference in processing temporally presented information is to use temporal or temporal-spatial ordering, they may also be more adept at handling other temporally presented material, such as reading, than are their spatially processing counterparts.

Although previous research has examined auditory and visual processing preferences of deaf individuals, it has not investigated the differential abilities of temporal, temporal-spatial and spatial processors and the relationship between method of processing and reading proficiency. Just as the visual-spatial nature of sign language is theorized to reinforce the spatial processing preference exhibited by deaf individuals (Karchmer et al., 1978), the auditory-sequential nature of spoken language is theorized to reinforce the time-based memory processing system used by hearing individuals (Downing & Leong, 1982). In view of the positive relationship reported to exist between temporal processing and reading achievement for hearing individuals (Doehring et al., 1981; Jarman, 1975; Shankweiler & Liberman, 1979; Torgesen, 1975), deaf temporal or temporal-spatial processors may prove to be better readers than their spatially-processing counterparts. Research investigating this hypothesis is yet to be reported in the literature and bears examination.

Another area reported in the literature as being important for reading ability is that of phonetic coding. This area will now be examined in more detail.

Phonetic Coding and Deafness

Reading is a complex task built upon a base of experience, and receptive and expressive language abilities (Myklebust, 1964). Mattingly and Kavanagh (1972), while agreeing that reading and listening employ the same linguistic processes, do not regard the two activities as totally parallel. Downing and Leong (1982) support this premise. For hearing individuals

> the language cues for speaking - listening are largely phonetic; the writing - reading cues involve the more abstract phonological coding and both listening and reading are linked by phonological rules (Downing & Leong, 1982; p. 98).

For deaf individuals who use sign language, the language cues are mainly visual-spatial. It is reasonable to suggest that lipreading and fingerspelling generally produce fleeting visual images and as such tax short term memory more so than does the written word. Visual imagery is regarded as a poor mechanism for retaining information as it is somewhat shorter and more transient than verbal short term memory (Paivio, 1971). Therefore, in order to retain information presented visually through lipreading or fingerspelling, the information must be verbally encoded for storage in short term verbal memory. Those deaf individuals who rely on visual short term memory for recall may be more susceptible to forgetting than those who rely on a more durable auditory store. Stored in visual short term memory, the information could be lost as a consequence of fading and distortion. However, in the absence of comprehensible speech, it is assumed that deaf individuals do not use phonological coding or articulatory cues but "decode written material directly into meaning" (Friedman, 1977; p. 348). Other researchers have examined deaf individuals' ability to use a variety of coding methods.

Dodd (1980) reported deaf subjects able to employ phonological, articulatory and graphemic information to assist recall. Conrad (1962; 1972), Conrad and Hull (1964) and Hintzman (1969) reported the use of both phonetic and visual coding.

Bellugi and Klima (1975) and Hoeman (1978) confirmed the deaf do employ manual representation of a sign to aid memorization and Locke and Locke (1971) have measured the use of phonetic, visual and dactylic coding to assist recall. Conrad (1962, 1963, 1964) and Locke and Locke (1971) used phonetically similar (B,P,T) and dissimilar (H,Q,R) consonants to determine the degree to which the deaf phonetically encode information in memory store and if, when items share a common feature, memory for items is affected.

Hearing subjects in the Conrad, and Locke and Locke studies were found to experience greater difficulty in recalling phonetically similar items whereas deaf subjects experienced equal difficulty with recall of both phonetically similar and dissimilar items. Conrad (1970a) and Conrad and Rush (1965), using phonetically similar (B,P) and shape similar (K,Y) consonants, distinguished two groups of deaf subjects, one being similar to hearing controls and experiencing greater confusion with the sound alike consonants and a second group which made substantial confusions with the shape-similar letters.

Conrad (1979) concluded that with hearing subjects, when material to be recalled is held in memory, although visual or semantic features may assist in recall, "the prominent information which defines and distinguishes items seems to be phonetic for immediate recall" (Conrad 1979, p.91). Although some deaf subjects appear to code visually and some phonetically, "the features of the set which are hardest to recall reflect the type of code principally used" (Conrad 1979, p.91).

Chen (1977) similarly reported deaf subjects as able to use phonological information for recalling pronounceable nonsense words when the graphemic code was unavailable. Dodd (1980) demonstrated that profoundly prelingually deaf children were able to use a phonological code to generate the spelling patterns for lipread nonsense words and when errors occurred, they were phonetically 'sound' and often appeared to reflect output strategy rather than perceptual difficulties. For example, although the deaf subjects often employed inaccurate articulation patterns, for example, /b/ and /m/ as /b/, their written productions were accurate. This finding seems to suggest that, at least for the deaf, oral expression, lipreading and written expression are distinct and that the strategic behavior required to generate information through each of these systems may also be distinct.

Using a similar procedure and more clearly defined groups, Locke and Locke (1971) found that deaf subjects with intelligible speech committed mostly phonetically similar errors while their unintelligible deaf group produced mainly visually similar confusions. For some deaf sign language users, fingerspelling is a constantly employed form of letter representation. The same information which can be abstracted from the visual (lipread or printed) form may also be available through the use of fingerspelling.

Bellugi and Klima (1974), and Hoeman (1978) reported deaf individuals to employ manual representation of signs to aid memorization. Shankweiler and Liberman (1979), using strings of phonetically confusable and non-confusable consonants, found phonetic ability to be directly related to reading ability with hearing individuals. Bisanz, Das and Mancini (1984), also working with hearing subjects and utilizing a parallel design but suppressing rehearsal, reported **rehearsal** to be a key factor in reading competency.

Rehearsal

Rehearsal as a strategy is the repetition or labeling of items to assist recall. It is reported to be successfully used by hearing individuals (Bisanz, Das, & Mancini, 1983; Torgesen, 1975) and deaf individuals (Conrad, 1979; Bellugi and Klima, 1974; Dodd, 1980; Hoeman, 1978; Locke & Locke, 1971) to aid recall.

Conrad (1979) reported deaf subjects may rely on alternate methods of rehearsal than those utilized by hearing individuals and that some deaf individuals perpetuate in using articulatory rehearsal even though its use may be detrimental to their recall. Contrary to this, Locke (1970) suggested the deaf "do not encode orthographic stimuli with a dactylo-kinesthetic system exclusively if at all" (p 233). However, this finding was based on subjective observation of the subjects during testing, as opposed to experimental control. Shankweiler and Liberman (1979) likewise noted this phenomenon, reporting that proficient hearing readers utilized a phonetic code even when their performance was penalized by its use.

With deaf individuals, it may be that once a strategy is learned, it is perpetuated until a more useful strategy is learned to take its place. Belmont, Karchmer, and Pilkonis (1976) postulated the memory deficiency reported by other researchers to be merely an expression of the well known language deficiency of the deaf. A factor contributing to this memory deficit may in fact be delayed or insufficient strategy usage.

For deaf sign language-using individuals, rehearsal could occur verbally, manually, or through the use of visual space. However, research has reported that deaf individuals poorly utilize strategies readily available within their own repetoire to assist recall (Conrad 1979; Martin, 1985). This finding has also been observed with learning disabled hearing individuals (Torgesen, 1975). Belmont et al. (1976) further reported sign-language using deaf school children to spontaneously develop rehearsal strategies at an older age (12 to 14 years) than their orally trained peers, who utilized rehearsal strategies by age 10 to 11. Hearing controls, on the other hand, exhibited spontaneous rehearsal by age 7 to 8 years.

Studies have not been reported with deaf subjects wherein auditory and manual rehearsal has been suppressed in order to determine whether a visual-spatial rehearsal approach has been adventitiously utilized. Conrad (1979) suggested the deaf may, in fact, use an auditory process at one point in time and in another similar situation, employ a visual process. The procedure described by Shankweiler and Liberman (1979) and modified by Bisanz, Das, & Mancini (1984) will be utilized in the present study to determine if the deaf use phonetic coding and if rehearsal is used beneficially to aid recall. This study will investigate whether those who use a phonetic code and rehearsal are also proficient readers.

In summary, the majority of the research dealing with reading ability and deafness has focused on the ability of the deaf population to use a phonological coding method. Although deaf learners are reported to use phonetic rehearsal (Chen, 1977; Conrad, 1979; Dodd, 1980; Locke & Locke, 1971), it has been reported that articulatory rehearsal may be detrimental to recall for some deaf individuals (Conrad, 1979).

It seems that the deaf are similar to hearing individuals and are capable of using phonetic coding. However, research also emphasizes that the phonetic code is not solely related to the auditory modality but that it may be abstracted from visual information such as that available from a lipread or fingerspelled form. Likewise, manual rehearsal has been reported to be used by deaf individuals for assisting recall (Bellugi & Klima, 1975; Dodd, 1980; Hoemann, 1978; Locke, 1970).

Conrad (1979), theorized that when processing information, the deaf may rely on alternate systems for memorizing than those used by the hearing population and may use an auditory process at one point in time and in another similar situation employ a visual process. If this is the case, the deaf may alternately use an intramodal and crossmodal method of processing depending on the nature of the material presented, thus supporting both the above points of view. However, based on the nature of the reading process, and in view of research earlier presented, it is possible the deaf may be delayed in the academic language areas as a result of the delayed onset of the 'developmental' or 'language' shift.

Research in the area of learning disabilities has identified a subgroup of reading disabled hearing children as being unable to use phonological information (dysphonetic dyslexic) (Boder, 1973), and as making 'phonologically poor' errors. It may be that a small subgroup of 'dysphonetic dyslexic deaf' exists within the deaf population. If such is the case, this may account for some of the inconsistency reported in the literature relative to the ability of deaf subjects to phonetically encode.

It may be that deaf students who encode information phonetically, or by other means, and who use rehearsal to assist recall will also be similar to their hearing counterparts and be functional readers. Patterns between deaf subjects permitted to rehearse and for whom rehearsal has been suppressed through the use of a concurrent articulatory and motoric suppression patterns have not been reported to date. By using a design similar to that of Bisanz et al. (1984) and examining reading ability, it may be possible to differentiate sub-groups of deaf individuals who utilize phonetic coding and rehearsal and are also good readers. If no significant difference in performance is found for phonetically confusable and non-confusable material in suppressed and non-suppressed conditions, it could be assumed that a visual-spatial method of recall has been used to aid recall. If this is found to be the preferred method of information processing for temporally presented material, it would seem appropriate to assist deaf individuals to develop rehearsal patterns which capitalize on this preferred method of processing.

The present study focuses on the coding of linguistic information and rehearsal in relationship to reading ability.

Definitions

The following definitions of terms have been used within the context of the present study:

Deafness is a disability in hearing to the extent which precludes the hearing and understanding of speech either with or without amplification (Fresina, 1974; Schein & Delk, 1974).

Severe hearing loss is determined by pure tone audiometry as being between 60 dB and 80 dB (ISO). Comprehension of speech is precluded without the use of a hearing aid (Frisina, 1974).

Profound hearing loss is determined by pure tone audiometry as being 80dB (ISO) or greater. Comprehension of speech is precluded with or without the use of amplification (Frisina, 1974).

Crossmodal ability involves the learning of a principle in one modality and then the employment of that principle to aid in the matching of a stimulus presented in a second modality (for example auditory then visual). The stimuli may not be identical for both modalities. Replicating

Jarman 1975, a proficient Crossmodal processor attains a score of 18 or more in 26 trials on the Visual-Auditory or Auditory-Visual tasks developed by Jarman (1975).

Intramodal ability involves both the learning and matching of a principle in only one modality (for example, Auditory then Auditory). A proficient Intramodal processor attains a score of 18 or more in 26 trials on the Visual-Visual or Auditory-Auditory tasks developed by Jarman (1975).

Spatial Processing involves the organization of information as a consequence of the manner in which it is presented in space and in relationship to other material presented through the same sense. Spatial processing generally utilizes the visual modality. In the present study a computer program will be used to measure this ability. Subjects will be presented with 10, three-digit strings and requested to record the digits seen on the screen. A spatial processor is one who records responses in more than 6 of the 10 trials in a spatial manner. A spatial response pattern follows the left-to-right position of placement of the digit stimuli.

Temporal Processing involves the organization of information as a consequence of the time-ordering of the presentation. Temporal processing generally occurs through the auditory modality. In the present study, the same computer program used to determine Spatial Processing will be used to measure Temporal Processing. A Temporal Processor is one who records responses in more than 6 of the 10 trials in a temporal manner. A temporal response pattern follows the sequential order of presentation of the digit stimuli.

Temporal-Spatial Processing involves the organization of information using a combination of time and space ordering. This method of processing generally utilizes a combination of both the auditory and visual modalities. In the present study, the same computer program used to determine the previously defined methods of processing will be used to measure Temporal-Spatial Processing. A Temporal-Spatial processor is one who, in 6 or more of the 10 trials, first records responses in a temporal fashion and, subsequent to viewing the array, changes the ordering of the pattern to appear in a spatial manner.

Random Processing involves the organization of information presented into a random response pattern such that no consistently discernible style of organization of data can be detected. A Random Processor is one who, on six or more of the ten trials, records responses such that no discernable pattern of response can be determined. Also within this group will be those who randomly choose digits to complete the digit strings. The same computer program used to determine the previously defined methods of processing will be used to measure Random Processing.

Phonetically Confusable representations are letters which, when vocalized (or sub-vocalized) may be made to rhyme with a similar type of information. When auditorally coded, these sound-alikes may become confused in working memory. Replicating research conducted by Shankweiler and Liberman (1979), and Bisanz, Das and Mancini (1984), Phonetically Confusable letters utilized in the present study were: **B C D G P T V.**

Phonetically Non-Confusable representations are letters which, when vocalized (or sub-vocalized) do not rhyme with a similar type of information. When auditorally coded, this type of information generally does not become confused in working memory. Replicating the same research cited above, Phonetically Non-Confusable letters utilized in the present study were: **H K L Q R S W.**

A **Suppression Condition** involves the use of a concurrent articulatory and dactylic procedure to prevent the rehearsal of phonetically presented material subsequent to the material being presented and prior to its being recorded by the subject. For the purpose of this study, suppression involves repeating **cowboy** vocally and bi-manually in sign for the 10-second interval immediately following the presentation of the phonetically confusable or non-confusable consonant strings and prior to recording responses on the form provided.

A **Standard Condition** involves the identical ten second time interval utilized in the Suppression Condition without the use of concurrent articulatory and dactylic procedure, thus allowing rehearsal of the presented material prior to its being recorded by the subject.

A **Graphemic Representation** is a letter symbol unit codified to denote a particular meaning. For the purpose of the present study, each grapheme was presented on a slide as a black-on-white single upper-case consonant letter unit. The consonants used were:

B C D G H K L P Q R S T V W.

A **Dactylic Representation** is a hand-shape symbol unit of fingerspelling codified to denote a particular meaning. For the purpose of the present study, each dactylic unit was presented on a slide as a black-on-white line drawing of the handshape denoting a particular consonant letter unit of fingerspelling. The consonants were the same as those used for the Graphemic Representations.

Summary

In summary, although similarities can be drawn between deaf and hearing individuals, they are reported to vary in the processing methods utilized in perceiving, remembering, transforming and utilizing information. Young hearing individuals are reported to rely primarily on an auditory, intramodal processing method when presented with linguistic information (Jarman, 1979). For proficient readers, this gives way to a crossmodal approach by approximately age seven. For deaf individuals, on the other hand, a visual, and thus an intramodal method of processing, is reported to predominate, regardless of method of input (Blair, 1957; Conrad, 1979; Hermelin & O'Connor, 1965; Karchmer et al., 1978; O'Connor & Hermelin, 1973;

Myklebust, 1964). Research has not been reported to date examining the possibility of a similar shift from intramodal to crossmodal method of processing with deaf individuals.

Although deaf learners are reportedly able to use various methods of processing information including phonetic coding (Chen, 1977), phonological, articulatory and graphemic codes (Dodd, 1980), both phonetic and visual codes (Conrad, 1979), a phonetic, dactylic and visual code (Locke, 1970) and manual representation (Bellugi & Klima, 1974; Hoeman, 1978), the method of processing information which predominates is reported to be visual-spatial, regardless of method of input (Blair, 1957; Hermelin & O'Connor, 1965; Karchmer et al., 1978; O'Connor & Hermelin, 1973).

In studies of memory, deaf learners have lagged behind their hearing peers in serial ordering tasks (Blair, 1957; Conrad, 1979; Wallace & Corballis, 1973) but have excelled in tasks of spatial location when compared with this same group (Blair, 1957).

The present study investigated the intramodal, visual-spatial processing preference reported to predominate for deaf individuals through use of a series of two intramodal and two crossmodal (visual and auditory) tasks as developed by Jarman (1975), and response patterns to a computerized spatial-temporal task. In addition, this study investigated the type and pattern of rehearsal utilized by this population. To achieve this end, phonetically confusable and non-confusable letter strings in suppressed and non-suppressed conditions will be utilized.

The study will also evaluate the degree to which performance on these measures relates to academic reading achievement as measured by performance on selected subtests of the Stanford Achievement Test - Hearing Impaired Edition (1982).

RESEARCH DESIGN AND METHODOLOGY

Rationale for the Study

The following section provides a description of the rationale for the study, the sample, a description of each task, and the hypotheses to be tested, followed by the experimental procedure.

Research dealing with deafness and learning has generally focused on the product of academic performance rather than its process. Until recently, very few researchers have attempted to investigate various learning processes used by deaf individuals, assuming that auditory deficit would be paralleled by absence of auditory processing and the deaf would therefore be unable to utilize linguistic information for recall. Recent research has suggested deaf learners in fact can phonetically encode as in the case of spelling (Dodd, 1980), memory (Conrad, 1963, 1964; Locke & Locke, 1971) and lipreading (Dodd, 1980). However, their preferred method of processing is reported to be visual (Dodd, 1980), spatial (Hermelin & O'Connor, 1964) or in some other yet unrecognized manner (Conrad, 1972). Deaf individuals have likewise been reported to experience difficulty with utilizing strategies efficiently to aid recall. In an effort to examine their ability in various areas of information processing, in the present study, subjects were administered a variety of tasks measuring selected aspects of information processing.

Research in the area of intramodal and crossmodal ability has been conducted with hearing subjects and verifies the close relationship between performance on crossmodal tasks and reading ability (Jarman, 1975, 1978, 1979, 1980; Torgesen, 1975). Similar research has not been conducted to date with a deaf population. Regardless of lack of evidence, research has postulated (Friedman, 1977) that the deaf, when reading, utilize an intramodal process rather than a crossmodal one. The relationship between crossmodal ability and reading ability has been well established within a hearing population. Since this area has been only superficially investigated within a deaf population, it is deemed necessary to establish the nature of this relationship.

Research has indicated that deaf individuals process information to a greater degree spatially than they do temporally. However, the stimuli generally utilized for measuring spatial processing do not easily lend themselves to being linguistically labelled, for example, photographs of faces (Blair, 1957). Additional research comparing spatial and temporal processing in hearing and deaf subjects has permitted alternate forms of recording, (verbal for hearing and written for deaf) such that the responses of the deaf group could be scored only as a spatial or a temporal response pattern when in fact, processing could have occurred in a spatial, temporal of a temporal-spatial manner.

The present study addressed this issue by utilizing a computerized recording mechanism which allows for determination of the exact mode of processing: spatial, temporal or a combination of these methods.

Until recently, one aspect of deafness which has not received much attention is the relationship between the ability to phonetically rehearse and reading proficiency. The survey of the literature presented earlier suggests the need for additional research to be conducted in this area.

When researching the area of deafness, homogeneous groupings of students must be used. Areas to consider include degree, cause, and age of onset of deafness and type of educational placement (Conrad, 1979). These considerations were taken into account when choosing the population for the present study.

In summary, the major purpose of the present exploratory study was:

1. To determine whether a relationship exists between performance on selected information processing measures and reading proficiency, which parallels that observed with learning disabled and normal populations. In pursuit of this goal, the study determined the following:

1.1 Whether performance on Intramodal and Crossmodal tasks can differentiate between good and poor readers within the theoretical framework of Jarman (1975).

1.2 Whether deaf students process linguistic information in a spatial, temporal, or temporal-spatial manner, and the relationship between method of processing and reading proficiency.

1.3 Whether deaf students use a phonetic code to recall information which is phonetically similar and/or dissimilar, using visually presented graphemic and dactylic material, within the theoretical framework of Shankweiler and Liberman (1979), and Bisanz, Das and Mancini (1984).

1.4 To examine the influence of rehearsal, as a strategy, on recall of visually presented linguistic information within the theoretical framework of Bisanz, Das and Mancini (1984).

1.5 To examine the relationship between phonological coding and rehearsal, and reading proficiency.

Sample

The sample consisted of 44 deaf students attending a Provincial School for the Deaf in Western Canada. The school served a total of 145 students aged 5.0 years to 19.0 years. The age criterion of the study reduced the total eligible population to 87 students. In addition, 26 students were not available for testing due to educational program requirements and 17 students were disqualified as they did not meet the screening criteria. The remaining 44 students comprised the total sample. The sample, consisting of 26 males and 18 females, was divided into two age groups - an older group (Group 1, X = age 17.3 years; N = 22) and a younger group (Group 2, X = age 13.6 years; N = 22). Table 1 presents sample descriptors for age, sex, cause of deafness and degree of hearing loss for Group 1 (Older Group), Group 2 (Younger Group), and for the Total Group. Criteria for the sample selection included the following:

1. Age: 12.0 years to 18.4 years.
2. Onset of deafness: prelingual deafness.
3. Hearing loss: unaided pure tone hearing loss greater than 80 dB. (ISO) in the better ear.
4. Handicaps: no additional handicapping conditions.

TABLE 1

Frequency Distribution of Subjects by Average Age in Months, Sex, Cause of Deafness and Unaided Pure Tone Average Degree of Hearing Loss

	GROUP 1 (OLDER GROUP) N=22	GROUP 2 (YOUNGER GROUP) N=22	TOTAL GROUP N=44
M AGE	207.27	162.64	184.96
SEX			
MALE	13	13	26
FEMALE	9	9	18
CAUSE			
GENETIC	6	8	14
ACQUIRED	10	8	18
UNKNOWN	6	6	12
AVERAGE UNAIDED HEARING LOSS			
LEFT	101.27	105.09	103.18
RIGHT	103.14	105.09	104.11

5. Intelligence Quotient: average to above average intellectual ability as measured on the Hiskey Nebraska Test of Learning Aptitude (1966).
6. Instructional Placement: attendance within a Total Communication program for deaf students for at least 5 years where an English based sign system was the language of instruction.

Of the 44 subjects, although all had been fitted with hearing aids within two years of the study, 19 reported seldom wearing their personal aids. The 18 good hearing aid users were evenly distributed between the two groups.

The remaining 7 subjects reported never wearing their hearing aids. A summary of hearing aid use is presented in Table 2.

TABLE 2

Hearing Aid Use of Subjects by Group Membership

	GROUP 1 (OLDER GROUP) N=22	GROUP 2 (YOUNGER GROUP) N=22	TOTAL GROUP N=44
Consistently Use aid(s)	9	9	18
Occasionally Use aid(s)	7	12	19
Never Use aid(s)	6	1	7
TOTAL	22	22	44

Experimental Tasks

The test battery described in this section was designed to determine a pattern of information processing of a sample of severely to profoundly deaf students. The relationship between this pattern and the students' individual academic performance was examined.

As a complete test battery was not available, assessment measures were selected from a variety of sources. These tasks measure **intramodal** and **crossmodal processing** (Jarman 1975), **spatial-temporal** ability (modification of Hermelin & O'Connor 1964), **phonetic coding** (Shankweiler & Liberman, 1979), and **rehearsal** (Bisanz, Das & Mancini, 1984). The measure of academic ability, The Stanford Achievement Test, Hearing Impaired Edition (1982) (SAT-HI), was administered by school personnel.

Following is a description of the experimental tasks utilized in the study. To facilitate reading of this section, it is presented in the following manner: first the purpose for using each task is presented; next, the task is described, followed by the procedure utilized and finally by the method used for scoring the task.

Intramodal and Crossmodal Tasks

PURPOSE

Following Jarman's procedure (1975), these tasks encompassed four separate components: Visual-Visual, Visual-Auditory, Auditory-Visual and Auditory-Auditory match. These tasks were utilized as a measure of Intramodal and Crossmodal ability in order to determine the relationship between proficiency on these tasks and reading ability.

VISUAL-VISUAL MATCHING TASK

This task is made up of sets of visual dot patterns, where the first pattern of each set is compared to the second pattern of the same set. For a dot of 2.5 mm in diameter, a short gap of

2.0 mm in length or a long gap of 18.0 mm in length is used to separate the dots and develop the pattern.

VISUAL-AUDITORY MATCHING TASK

This task involves matching a stimulus pattern of dots with a comparison pattern of tones. Each tone is of 1000 cycles per second and of 0.15 second duration. Variation in tone patterns are created by utilizing short pauses of 0.35 second or long pauses of 1.35 seconds in duration.

AUDITORY-VISUAL MATCHING TASK

This task is the converse of the Visual-Auditory matching task. The auditory tone pattern acts as the stimulus pattern to be compared with the visual dot display.

AUDITORY-AUDITORY MATCHING TASK

This task is made up of sets of Auditory tone patterns as described above, where the first pattern of each set is compared with a second auditory pattern.

PROCEDURE

Subjects were tested in class groups of 6 to 8 students while seated in a semi-circle and equidistant from the viewing screen and tape recorder. Those students without personal hearing aids were fitted with group amplification devices (Phonic Ear). At the commencement of each task involving the auditory modality, the auditory sample items were used repeatedly while adjusting the volume of the tones on the tape recorder and students' personal amplification to meet the auditory need of each student group.

The dot patterns (Appendix A) were simultaneously presented using a slide projector and a programmable output control device. The patterns of tones were recorded on an audio tape together with the instructions for completing the task. The instructions for each of the modality matching tasks as developed by Jarman (1975) were signed to the subjects. Sample items were reviewed additional times if subjects were unsure of the instructions. After each stimulus pattern of two items, students were required to decide if the two patterns were the same or different. After each matched set, subjects were given 10 seconds to record their answer on an answer sheet provided (Appendix B) by circling their answer, **Same** or **Different.** Each of the tasks required approximately 8 minutes to complete and a total time of approximately 32 minutes.

The Visual-Visual Task was presented first of the modality matching tasks in order to use it as a training as well as a test measure. This was done so that all subjects would be familiar with the test procedure prior to employing the tasks using the auditory modality, as these tasks were felt to be potentially more difficult for the population under investigation, due to the severity of their hearing loss.

SCORING

A score of one was given for each correct response for a maximum possible score of 26 points. Criterion required a score of 17 out of 26 to control for guessing.

Spatial-Temporal Task

PURPOSE

This task was utilized as measures of Temporal, Spatial, and Temporal-Spatial ability in order to determine the relationship between method of processing and reading ability.

TASK

An Apple computer was used with each student to display three practise strings and ten test strings (Appendix C), each of three single digits (1-9) in a successive fashion. Each digit was visible for 500 msec. There was a 250 msec. delay between each of the digits of each digit string. Selection and order of digits as well as spatial and temporal ordering of digits at equally spaced positions across the screen, was random.

PROCEDURE

Subjects were tested individually in a small office area at the same school from which the population was selected. Subsequent to the completion of the display, subjects were asked to respond by entering into the computer, the numbers observed on the screen. Each subject's answers, when entered, were automatically stored on a computer disc. Prior to the presentation of the next digit string, the digits, or their order, could be altered by the subject with changes also recorded on the disc. If clarification was requested, subjects were instructed to enter the numbers seen on the screen in the manner most comfortable to the subject. Instructions for this task are presented in Appendix D.

SCORING

Method of processing was determined by examining the responses made by each student. Method of response was scored as Temporal, Spatial, Temporal Spatial, or Random.

Phonetically Confusable and Non-Confusable Graphemic Tasks

PURPOSE

This task was used as a measure of phonetic coding in order to determine the relationship between phonetic coding of visually presented meaningful information and reading proficiency.

TASK

Paralleling the procedure used by Shankweiler and Liberman (1979) and Bisanz, Das and Mancini (1985), phonetically similar (rhyming) graphically presented consonants, **B,C,D,G,P,T,V** and phonetically dissimilar (non-rhyming) graghically presented consonants, **H,K,L,Q,R,S,W** were each used to create eighteen, five-letter strings of consonants. The thirty-six, five-letter strings (Appendix E) were then arranged into three sets of consonant strings consisting of two practise strings and 10 test strings each. Each letter appeared only once in each string and a maximum of three times in each serial position per set. The rhyming and non-rhyming strings were randomly ordered while allowing both a rhyming and a non-rhyming string to appear as one of the two practice sessions which preceded each set of letter strings. The number of concurrent presentations of rhyming and non-rhyming strings was restricted to two.

PROCEDURE

The black-on-white image of each upper-case letter was prepared and centered on a 5x5 cm. slide to be projected in succession onto a screen using a 35 mm. projector equipped with a programmable output-control device. Subjects were tested in class groups while sitting in a semi-circle and equidistant from the viewing screen. Instructions for this task (Appendix F) were signed to the subjects. Prior to the commencement of each letter string, the subjects were asked, **Ready**? If all subjects indicated **Yes**, the examiner pointed to the screen immediately preceding the timing device being activated.

Three sets of both a Standard and a Partial Suppression Condition were presented. In the Standard Condition, replicating

Shankweiller and Liberman (1979), each letter string was preceded by an asterisk which served as an alerting stimulus. This remained on the screen for 500 msec. Each letter-slide was projected for 500 msec. with an interval between each slide of one second. At the end of each string and after a 10 second delay, subjects were given as much time as required to record the letters recalled on the page of a booklet having five blank spaces (Appendix G). Subjects were carefully instructed to write their answers in relation to what had been seen on the screen.

Replicating research reported by Bisanz, Das and Mancini (1984), a Partial Suppression Condition was identical to the Standard Condition with the exception that subjects were asked to quickly repeat **Cowboy** subsequent to the presentation of each letter string, both vocally and bi-manually throughout the 10 second delay interval.

SCORING

A strict scoring method as described by Shankweiler and Liberman (1979) was used. In this scoring method, an error is counted when an item is incorrectly identified, or assigned to an incorrect serial position. A score of 25 could be obtained on the two segments of each set of responses. The scores for each of the three sets of tasks for each condition were averaged. The resulting score wasutilized as the measure of performance.

A record was also kept of the number of **similar** errors and **non-similar** errors committed in recording responses. Similar errors could occur in the Phonetically Confusable letter strings. They could be sound-similar or shape-similar. Sound-similar errors sound the same as one of the five string letters but were not included within the test string (eg. B for P) or were recorded out of position (eg. B presented in the first position and recorded in the third position); shape-similar errors could have graphemic similarity (eg. O for C) or shape-similar errors for dactylic similarity (eg. N for T). Non-Similar errors could occur in the Phonetically Non-Confusable letter strings and could be sound-similar (eg. J for K), shape-similar for graphemic similarity (eg.M for W) or shape-similar for dactylic similarity (eg. P for K).

Phonetic Confusable and Non-Confusable Dactylic Tasks

PURPOSE

This task was used as a measure of phonetic coding in order to determine the relationship between phonetic coding of visually presented meaningful information and reading proficiency.

TASK

This task parallels that of the previous (Graphemic) task with the exception that the letters were presented as black-on-white line drawings of the hand configurations of the consonants as represented by the manual alphabet of fingerspelling.

PROCEDURE

The procedure and conditions for this task parallel those of the preceding task. Both Standard and Partial Suppression Conditions were presented. Three sets of both the Standard and Partial Suppression Conditions were administered (Appendix H). The instructions and response form used were the same as for the Graphemic tasks.

SCORING

The scoring method parallels that of the previous task. The maximum score that could be achieved was 25 points for each condition.

Academic Tasks

PURPOSE

Measures of Academic achievement were used to determine the academic functioning level of students.

TASK

The students' individual scores obtained on the Vocabulary (Voc), Reading Comprehension (RC) and Mathematical Computations (MC) subtests of the SAT-HI (1982) were utilized.

PROCEDURE

This measure of academic achievement is administered in the spring of each school year by the classroom teacher. Standardized administration procedures, as outlined in the assessment manuals, are utilized.

SCORING

Grade level scores were derived from the students' raw scores obtained on each subtest. The grade level scores thus obtained were used as a measure of academic success for each of the Vocabulary, Reading Comprehension and Mathematics Computation Subtests. Grade equivalent scores could range between 0 Grade level and 12.9 Grade level.

General Procedure:

The tasks were administered by the author with the help of two research assistants who were trained by the author.
The research was carried out at the school from which the sample was drawn. Subjects were tested in groups of 6 to 8 for all tasks with the exception of the spatial-temporal task. The latter task was administered individually with each student using an Apple computer. The subjects were administered all the tasks in either four or five sessions. Three to four, forty minute class periods were used for the group presentations. The Temporal-Spatial task was completed individually with each student in 10 to 15 minutes.

Pilot testing of the material indicated that a short example sequence rather than a formal prescriptive announcement ensured the speediest and most secure understanding of the task requirements. Accordingly, an informal and interactive approach was adopted. In administering the tasks, the following procedural points were considered: 1) establishing rapport with the individual prior to the administration of the test battery, 2) clarity of instruction, 3) inclusion of sample trial(s) prior to the administration of each task and 5) observation of the individual(s) during the testing situation.

During those test sessions requiring the use of audition, students were requested to use their own personal amplification. Group amplification devices (Phonic Ear) with headphones were provided to those students without personal hearing aids.

With the exception of the Visual-Visual task being presented first of the modality matching tasks, and the Temporal-Spatial task being last, the sets within each group of tests were presented in a randomized order to balance any potential of learning transfer from one task to the next.

Major Hypotheses

HYPOTHESIS I

Measures used to measure learning processes with learning disabled and normal populations can be utilized with a deaf population.

HYPOTHESIS II

There will be a strong positive relationship between Crossmodal ability and reading proficiency. There will be little or no relationship between Intramodal processing and reading proficiency.

HYPOTHESIS III

Temporal and Temporal-Spatial processors will demonstrate greater proficiency in processing information in a Crossmodal manner, while Spatial processors will demonstrate greater proficiency in processing information in an Intramodal manner.

HYPOTHESIS IV

Temporal and Temporal-Spatial processors will exhibit greater proficiency in academic performance than will Spatial processors.

HYPOTHESIS V

Good readers will demonstrate significantly more errors on phonetically confusable (rhyming) tasks than on phonetically non-confusable (non-rhyming) tasks, both dactylic and graphemic. This will be consistent for both age groups.

HYPOTHESIS VI

Poor readers will demonstrate no significant difference in number of errors on phonetically confusable and non-confusable letter tasks, both dactylic and graphemic. This will be consistent for both age groups.

RESULTS AND DISCUSSION

This chapter deals with the findings directly relevant to the hypotheses previously presented. To facilitate reading, the relevant hypotheses will precede each section. Since the main concern of the study was to determine the relationship between selected learning processing measures and reading proficiency, the discussion of the results will emphasize this aspect.

This chapter has been organized into five sections, each presenting the results and a discussion of the findings. The first section addresses the capabilities of the subjects on the information processing measures used in the present exploratory study. The next three sections deal with the performance of the Older, Younger, and Total Group on (1) the Intramodal tasks (Visual-Visual [VV] and Auditory-Auditory [AA]) and Crossmodal tasks (Visual-Auditory [VA] and Auditory-Visual [AV]); (2) the spatial temporal tasks and (3) the phonetically confusable and non-confusable tasks. Task performance and its relationship to academic reading ability is discussed in each of these sections. In the final section, (4) both groups are collapsed together and subjects' performance on the crossmodal and intramodal and the phonetically confusable and non-confusable tasks used to separate the subjects into **clusters**.

In order to achieve this goal, first, means and standard deviations were calculated for the crossmodal and intramodal, phonetically confusable and non-confusable, and academic tasks for each of the three groups. For the temporal spatial tasks, a frequency distribution for each group was completed, followed by a comparison of the mean performance levels on the academic tasks for the groups of Spatial, and Temporal and Temporal-Spatial processors .

Then, correlational analyses were carried out for the crossmodal and intramodal and the phonetically confusable and non-confusable measures followed by correlational analyses for these and the academic measures with age and degree of hearing loss. Next, in order to determine whether differences between proficient and non-proficient performers could be discerned on the test measures, a series of discriminant function analyses was carried out.

A cluster analysis was then carried out with performance on the crossmodal and intramodal and the phonetically confusable and non-confusable measures serving as the Independent variables, and Cluster Membership as the Dependent variable. Two separate ANOVA'S were then carried out, one with **Age,** and one with **Degree of Hearing Loss** serving as the

Dependent measure and **Cluster Membership** serving as the Independent measure for each ANOVA respectively. Multiple comparison SCHEFFE'S T TEST were conducted to determine the significance of the differences among the clusters. Finally, qualitative observations of the subjects as they relate to task performance and communication skills were provided.

Measures of Information Processing

Hypothesis I states:

Measures used to measure learning processes with normal and learning disabled populations can be utilized with a deaf population.

The means and standard deviations for the Jarman, Shankweiller-derived and Academic tasks are presented in Tables 3, 4 and 5 for the Older Group (Group 1), for the Younger Group (Group 2) and for the combined sample (Total Group) respectively . Results will be discussed in the order presented in the tables. Documentation related to the Temporal/Spatial task is presented in a later section of this chapter.

The Jarman tasks were used to determine whether deaf subjects process information intramodally or crossmodally. Two Intramodal and two Crossmodal tasks, each of 26 item pairs, were presented to the subjects who were required to judge whether the pairs of items were the same or different. Proficiency on the task required correctly matching 17 of the 26 item pairs.

On the Intramodal VV task, both groups performed well and reached ceiling on this task. This finding may be directly

TABLE 3

Performance of Group 1 (Older Group) on Intramodal and Crossmodal Tasks, Phonetically Confusable and Non-Confusable Tasks, and Academic Tasks

Variable	Mean	Standard Deviation	Minimum	Maximum	Number
VIS/VIS	24.77	1.97	19.00	26.00	22
VIS/AUD	22.77	3.04	18.00	26.00	22
AUD/VIS	20.23	4.66	12.00	26.00	22
AUD/AUD	18.41	6.01	10.00	26.00	22
LNSC	12.41	5.06	6.00	25.00	22
LNSNC	11.96	5.54	4.00	25.00	22
LSC	8.50	4.64	0.00	10.00	22
LSNC	8.55	3.91	3.00	21.00	22
DNSC	12.50	6.61	2.00	24.00	22
DNSNC	12.41	5.71	3.00	24.00	22
DSC	9.27	5.04	0.00	23.00	22
DSNC	9.50	5.35	0.00	23.00	22
NS ERROR	1.46	1.18	0.00	4.00	22
S ERROR	2.32	1.43	1.00	6.00	22
VOC	3.44	1.75	1.20	6.80	22
R.COMP	5.15	1.69	2.00	7.90	22
MA.COMPU	8.28	2.12	4.30	12.90	22

VIS — Visual
AUD — Auditory
L — Letters
D — Dactylic

NS — Non-Suppressed
S — Suppressed
NC — Non-Confusable
C — Confusable
NS ERROR — Non-Similar Errors
S ERROR — Similar Errors

VOC — Vocabulary (SAT-HI)
R.COMP — Reading Comprehension (SAT-HI)
MA.COMPU — Mathematics Computation (SAT-HI)
SAT-HI — Stanford Achievement Test - Hearing Impaired Edition

TABLE 4

Performance of Group 2 (Younger Group) on Intramodal and Crossmodal Tasks, Phonetically Confusable and Non-Confusable Tasks, and Academic Tasks

Variable	Mean	Standard Deviation	Minimum	Maximum	Number
VIS/VIS	24.18	2.72	14.00	26.00	22
VIS/AUD	18.32	4.83	10.00	26.00	22
AUD/VIS	16.86	4.54	8.00	25.00	22
AUD/AUD	15.00	5.42	2.00	23.00	22
LNSC	10.23	5.16	3.00	24.00	22
LNSNC	10.32	4.96	2.00	25.00	22
LSC	8.32	5.49	2.00	25.00	22
LSNC	7.77	4.35	1.00	16.00	22
DNSC	10.05	4.68	3.00	23.00	22
DNSNC	11.32	5.77	3.00	22.00	22
DSC	7.73	5.49	1.00	21.00	22
DSNC	6.91	4.85	1.00	19.00	22
NS ERROR	1.18	1.01	0.00	3.00	22
S ERROR	1.77	1.23	0.00	5.00	22
VOC	2.80	1.88	0.20	7.60	22
R.COMP	4.16	1.91	2.00	8.60	22
MA.COMPU	6.90	1.92	3.20	11.60	22

VIS — Visual
AUD — Auditory
L — Letters
D — Dactylic

NS — Non-Suppressed
S — Suppressed
NC — Non-Confusable
C — Confusable
NS ERROR — Non-Similar Errors
S ERROR — Similar Errors

VOC — Vocabulary (SAT-HI)
R.COMP — Reading Comprehension (SAT-HI)
MA.COMPU — Mathematics Computation (SAT-HI)
SAT-HI — Stanford Achievement Test - Hearing Impaired Edition

TABLE 5

Performance of Total Group on Intramodal and Crossmodal Tasks, Phonetically Confusable and Non-Confusable Tasks, and Academic Tasks

Variable	Mean	Standard Deviation	Minimum	Maximum	Number
VIS/VIS	24.48	2.37	14.00	26.00	44
VIS/AUD	20.55	4.58	10.00	26.00	44
AUD/VIS	18.55	4.85	8.00	26.00	44
AUD/AUD	16.71	5.91	2.00	26.00	44
LNSC	11.32	5.17	3.00	25.00	44
LNSNC	11.14	5.26	2.00	25.00	44
LSC	8.41	5.03	0.00	25.00	44
LSNC	8.16	4.11	1.00	21.00	44
DNSC	11.27	5.80	2.00	24.00	44
DNSNC	11.36	5.77	3.00	24.00	44
DSC	8.50	5.27	0.00	23.00	44
DSNC	8.21	5.21	0.00	23.00	44
NS ERROR	1.32	1.10	0.00	4.00	44
S ERROR	2.05	1.35	0.00	6.00	44
VOC	3.12	1.83	0.20	7.60	44
R.COMP	4.65	1.85	2.00	8.60	44
MA.COMPU	7.59	2.12	3.20	12.90	44

VIS — Visual
AUD — Auditory
L — Letters
D — Dactylic

NS — Non-Suppressed
S — Suppressed
NC — Non-Confusable
C — Confusable
NS ERROR — Non-Similar Errors
S ERROR — Similar Errors

VOC — Vocabulary (SAT-HI)
R.COMP — Reading Comprehension (SAT-HI)
MA.COMPU — Mathematics Computation (SAT-HI)
SAT-HI — Stanford Achievement Test - Hearing Impaired Edition

related to the nature of the VV task itself which is primarily visual, resulting in high performance being achieved on this task with relative ease and a ceiling effect becoming evident. This finding is in keeping with research results in the area of deafness where the deaf are reported to do well on visual tasks (Blair, 1957; Conrad, 1979). For example, on the VV task, out of a total possible score of 26, Group 1 received a mean score of 24.77, a standard deviation of 1.97 and a range of 19 to 26 (Table 3). This result was consistent with the findings for Group 2 and the Total Group.

On the Intramodal AA task, the mean score achieved by Group 1 (M 18.41; SD 6.01; range 10 to 26) revealed they were able to perform this task proficiently. Although some of the members of Group 2 were also able to perform this task proficiently (range of scores 2 to 23), their mean score was below that required for proficient performance (M = 15.00; SD 5.42). The mean for the Total Group (M = 16.71; SD 5.91: range 2 to 26) was likewise below that required to indicate proficient Intramodal ability on the AA task.

On the Crossmodal VA and AV tasks, scores obtained by Group 1 revealed proficient Crossmodal ability on both measures. However, their performance on the VA task resulted in less score variance, higher mean score and lower standard deviation than obtaind on the Crossmodal AV task. Although the same general pattern was evident with Group 2, they were proficient on only the Crossmodal VA task, their mean Crossmodal AV score falling below that required for proficiency (M = 16.86; SD 4.54). Mean scores obtained by the Total Group indicated proficient Crossmodal ability for both the VA and AV tasks.

Jarman's theory states that Intramodal skills must develop prior to Crossmodal ability being mastered. However, a comparison of means across the four tasks and two groups (Tables 3, 4 and 5) indicated that the sample as a whole had not mastered both Intramodal tasks. In fact AA, an Intramodal task, reflected poorest performance for both groups. This finding may be attributed to the nature of the AA task, which utilized successive processing and required auditory input to be stored in short-term memory and subsequently retrieved and compared to another auditory stimulus which also had to be held in short-term memory in order that a comparison be made. Therefore, when the auditory stimulus became the primary stimulus for comparison, even when the second stimulus was visual, the storing of the primary stimulus could be difficult. In fact, of the CMIM tasks, the AV task recorded the second lowest mean score for each group.

When the two stimulus patterns were visual, all subjects performed equally well and both group means approached ceiling on this task (Group 1: $\underline{X} = 24.77$; $\underline{SD}$ 1.97; Group 2; $\underline{X} = 24.18$; $\underline{SD}$ 2.72). When the stimulus pattern which must be held in short term memory was visual and the comparison pattern was auditory, the older group significantly outperformed the younger ($\underline{f}=3.11$; $\underline{df}=1,39$; $\underline{p}<.05$). This finding may be indicative of this Crossmodal ability (VA) significantly improving with age.

A comparison of mean scores for Group 1 and Group 2 on all of the Intramodal and Crossmodal tasks indicated an increase in mean scores with age. This finding may be indicative of both Intramodal and Crossmodal abilities improving with age. This finding is in keeping with research conducted with hearing subjects (Jarman, 1975; 1979; Sterritt & Rudnick, 1980). Although the present results appear to confirm that Jarman's tasks are usable with deaf subjects, this area should be investigated with a larger population and wider age range than that used in the present exploratory study.

The Shankweiler-derived tasks were used to examine the phonetic coding ability of the study group. Phonetically confusable and non-confusable consonant strings, each of five letters, were visually presented in both non-suppressed and suppressed conditions. Consonants were presented as letter and as dactylic handshape units. The number of similar and nonsimilar errors committed on each of the trials were averaged separately for the Graphemic and Dactylic task sets.

In examining the scores obtained by both groups separately and for the combined group, the same general pattern of performance was evident for both letter and dactylic tasks (See Tables 3, 4 & 5). Therefore the discussion of the performance ability of subjects in relation to these two sets of data will be presented simultaneously.

In the non-suppressed conditions, both Phonetically Confusable (PC) and Non-Confusable (NC) consonant strings were recalled with striking similarity for subjects within each group. However, the Older Group (Group 1) obtained higher mean scores on both PC and NC conditions than those obtained by Group 2. The same general pattern of responses was also apparent for the Suppressed conditions, again with Group 1 achieving slightly higher mean scores than those obtained by Group 2.

A comparison of the Suppressed (S) and Non-Suppressed (NS) conditions reveals overall better performance on the **NS** than on the **S** condition. This finding indicates that rehearsal of some type was being used during the **NS** condition. However, as similar mean scores were obtained for **PC** and **NC** consonant strings in comparable conditions (letter and dactylic), neither phonetic nor dactylic coding appeared to be the method of rehearsal employed by the study group. It would appear, then, that visual rehearsal may have been employed.

However, a comparison of error types reveals that more similar than non-similar errors were committed both by Group 1, Group 2 and the Total Group. A similar error could result from a sound-similar or shape-similar consonant being substituted for one of the stimulus consonants. In order for such errors to be committed, the subjects must have used phonetic and/or dactylic rehearsal in attempting to recall the consonant strings presented.

Although these results appear to contradict one another, it may be that the deaf subjects in the present study had strategies available to aid their recall but these strategies were too inefficiently or insufficiently utilized to produce a readily discernible pattern of skill. Additionally, they may have used one strategy in one situation and in another, similar situation, utilized an alternate strategy. This possibility will be further discussed within the context of the present exploratory study. However, as subjects in the present study were able to recall consonants presented, the Shankweiler-derived tasks appear to be appropriate to use with a deaf population.

Student's performance on subtests of the Stanford Achievement Test Hearing Impaired Edition (SAT-HI) (1982) were utilized in order to determine whether a relationship could be discerned between performance on the learning processing measures utilized in the present study, and the academic ability of the subjects in the groups. The SAT-HI subtests used were Vocabulary (Voc), Reading Comprehension (RC), and Mathematical Computation (MaCompu).

Although on each of the academic measures, subjects in Group 1 achieved greater mean scores than subjects in Group 2, the size of the Standard Deviation for each academic achievement area subsumes the mean score achieved by the other group on the same subtest. For example, on **Voc**, Group 1 achieved a mean score of Grade 3.44 years and a Standard Deviation of 1.75. This grade range spans Grade 1.69 to Grade 5.19. The Mean Grade Score obtained by Group 2 on this same measure is Grade 2.80, a Mean score within the possible range of scores obtained by Group 1. Therefore, the range of scores for the two groups overlap. This finding also applies to the other academic measures.

The minimal differences in mean grade scores obtained by the subjects in the present exploratory study are in keeping with research cited earlier wherein deaf students are reported to show minimal growth in their academic skills over time on academic measures such as the SAT-HI (Di Francesca, 1972; Di Francesca & Carey, 1972; Gentile, 1963; Trybus & Jensema, 1976; W0lk & Allen, 1984). Therefore, although this is the device most commonly used to measure the academic ability of deaf, North American school children, it may not be possible to determine whether a relationship exists between performance on the learning processing measures used in this study, and the academic ability of the subjects in the groups, as the differences in academic performance between Group 1 and Group 2 on the three academic measures are minimal at best.

Tables 3, 4 and 5 do not present data related to the Spatial-Temporal tasks, due to the nature of the spatial-temporal data. Whereas the Jarman, Shankweiler-derived, and Academic tasks resulted in a range of scores, completion of the Spatial-Temporal task resulted in only the determination of method of processing.

The Spatial-Temporal task was completed individually by each subject using an Apple computer. The three, 10-digit arrays presented on the computer screen were to be reproduced by the subjects. Responses were scored as Spatial, Temporal, Temporal-Spatial or Random responses. When more than six of the ten-digit strings were recorded temporally, the subject was termed a **Temporal processor.** Likewise, if more than six of the ten-digit strings were recorded spatially, the subject was termed a **Spatial processor. Temporal Spatial processors** were those who, on more than six of the test strings, first recorded their responses in a temporal fashion and then changed their answers to be in a spatial array. **Random processors** were those for whom no consistently discernible response pattern could be identified. Also included in this group were subjects who randomly chose numbers, other than those presented on the screen, to complete the pattern.

A breakdown of subjects by group membership is presented in Table 6. As can be seen from Table 6, the majority of subjects were Spatial processors (72.73%). A smaller number used either Temporal or Temporal-Spatial processing (20.45%), while for 3 of the subjects, no consistently discernible pattern of response could be determined. These subjects were termed Random Processors. Of the Random processors, one from each of the two different age groups used Spatial processing for half of the 10 digit strings and Temporal processing for the other half. The other Random processor from Group 1 randomly chose digits to complete each array.

The large majority of subjects (93.18%) were able to successfully complete this task, and were classified as Spatial, Temporal or Temporal-Spatial processors. The Spatial and Temporal processors are divided between the two groups. The Temporal-Spatial processors are all from Group 1. The method of processing of the remaining 6.81% could not be discerned. As 41 of the 44 subjects proficiently completed this task, it is within the ability level of the majority of this population and it is therefore reasonable to suggest that this task can be used with deaf subjects.

TABLE 6

Frequency Distribution of Subjects
by Method of Processing

METHOD OF PROCESS	GROUP 1 (OLDER GROUP) N=22	GROUP 2 (YOUNGER GROUP) N=22	TOTAL GROUP N=44
Spatial	14	18	32
Temporal	2	3	5
Temp/Spat	4	0	4
Random	2	1	3

As each of the learning process measures used in the present exploratory study appears to be appropriate for use with deaf subjects, Hypothesis I is accepted.

Crossmodal and Intramodal Tasks

Hypothesis II states:

> There will be a strong positive relationship between Crossmodal ability and reading proficiency. There will be little or no relationship between Intramodal processing and reading proficiency.

Correlations among the Jarman tasks, Shankweiler-derived and Academic measures were carried out separately combining all subjects whose ages ranged between 16 years 1 month to 18 years 9 months (Group 1) and 12 years 1 month to 14 years 9 months (Group 2). In addition, correlations were also carried out combining both age levels (Total Group). This statistical procedure was adopted since a focus of the study was to investigate deaf students across the age range of twelve to eighteen years. In addition, analyzing each age range separately could produce low correlation scores due to the restriction of range.

Moreover, the size of a correlation is dependent upon the variability of the measured values in the correlated sample. Therefore, "the greater the variability, the higher should be the correlation, given that everything else is equal" (Guilford, 1965, p.341). Thus the correlations of the Total Group should be more indicative of the actual significance of the correlations. However, this point does not suggest ignoring the correlations carried out with Group 1 and Group 2 separately.

The intercorrelation matrices are presented in Table 7, Table 8 and Table 9 for Group 1, Group 2 and the Total Group respectively. The correlation matrices for the Jarman tasks, the Shankweiler-derived tasks and the Academic measures were derived from the raw scores of the 22 subjects for each of Group 1 and Group 2 and from the the scores of all 44 subjects for the Total Group. Discussion of the data relative to the Jarman measures will occur in the present section, with discussion of the Shankweiler-derived tasks occurring later in this chapter.

As can be seen from Tables 7, 8 and 9, for the **Intramodal** tasks, (Visual-Visual [VV] and Auditory-Auditory [AA]) and the **Crossmodal** tasks, (Visual-Auditory [VA] and Auditory-Visual [AV]), the intercorrelations for Group 1 and the Total Group are moderately high between the Crossmodal

TABLE 7

Correlation Table (Group 1) (Older Group)

	VIS VIS	VIS AUD	AUD VIS	AUD AUD	LC NS	LNC NS	LC S	LNC S	DC NS	DNC NS	DC S	DNC S	VOC	RC	MA COMPU
VV															
VA	-.04														
AV	.31	.63***													
AA	.28	.71***	.81***												
LCNS	-.38*	.38*	.33	.19											
LNCNS	-.05	.60**	.58**	.52**	.77***										
LCS	.14	.47**	.46**	.26	.54**	.70***									
LNCS	.20	.36*	.32	.31	.44**	.54**	.58**								
DCNS	.11	.48**	.63***	.47**	.62***	.52**	.63***	.59*							
DNCNS	.42*	.43*	.59**	.47**	.31	.39*	.53*	.56*	.73***						
DCS	.42*	.41*	.35*	.31	.22	.30	.54*	.54*	.65**	.66***					
DNCS	.25	.42*	.52**	.36*	.51**	.50**	.59*	.58*	.69***	.81***	.51*				
VOC	.10	.28	.11	.12	.24	.09	.31	.61***	.56**	.66***	.66***	.59**			
RC	.08	.51**	.30	.36*	.04	.17	.41*	.35*	.45**	.58**	.71***	.51**	.63***		
MACOMPU	.26	.39*	.29	.39*	-.02	.19	.15	.18	.28	.46*	.68***	.39*	.39*	.71***	

*	<.05	VIS	Visual	L	Letters	C	Confusable	S	Suppressed	VOC	Vocabulary
**	<.01	AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed	RC	Reading Comprehension
***	<.001									MACOMPU	MathComputation

TABLE 8

Correlation Table (Group 2) (Younger Group)

	VIS VIS	VIS AUD	AUD VIS	AUD AUD	LC NS	LNC NS	LC S	LNC S	DC NS	DNC NS	DC S	DNC S	VOC	RC	MA COMPU
VV															
VA	.33*														
AV	.26*	.32*													
AA	.22	.29	.61***												
LCNS	.11	-.02	.30*	.35**											
LNCNS	.24	-.04	.47**	.23	.81***										
LCS	.08	-.14	.12	.19	.81***	.75***									
LNCS	.15	-.32*	.36*	.36*	.67***	.69***	.64***								
DCNS	.13	-.15	.22	.13	.85***	.80***	.82***	.65***							
DNCNS	.18	-.08	.47***	.13	.68***	.79***	.77***	.61***	.73***						
DCS	.34*	-.32*	.22	.10	.58**	.79***	.67***	.68***	.72***	.64***					
DNCS	.32	-.30	.06	.15	.51**	.61***	.69***	.70***	.72***	.50**	.87***				
VOC	.43**	.08	.24	.18	.63***	.70***	.73***	.50**	.71***	.73***	.72***	.72***			
RC	.31	.11	.25*	.36*	.73***	.71***	.80***	.54**	.72***	.71***	.64***	.67***	.87***		
MACOMPU	.09	-.12	.02	-.03	.67***	.66***	.75***	.47*	.79***	.77***	.65***	.63***	.82***	.68***	

*	<.05	VIS	Visual	L	Letters	C	Confusable	S	Suppressed	VOC	Vocabulary
**	<.01	AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed	RC	Reading Comprehension
***	<.001									MACOMPU	Math Computation

TABLE 9

Correlation Table (Total Group)

	VIS VIS	VIS AUD	AUD VIS	AUD AUD	LC NS	LNC NS	LC S	LNC S	DC NS	DNC NS	DC S	DNC S	VOC	RC	MA COMPU
VV															
VA	.24*														
AV	.30*	.52**													
AA	.26*	.51**	.75***												
LCNS	-.07	.22	.37	.31*											
LNCNS	.13	.26*	.55***	.42**	.79***										
LCS	.10	.07	.27*	.22	.67***	.71***									
LNCS	.18	-.01	.34**	.35**	.57***	.61***	.61***								
DCNS	.14	.22	.49***	.38*	.72***	.63***	.68***	.61***							
DNCNS	.29*	.19	.55***	.34*	.52***	.59***	.65***	.59***	.73***						
DCS	.38**	.03	.31*	.24	.43**	.55***	.61***	.62***	.67***	.66***					
DNCS	.30*	.12	.36**	.32*	.53***	.57***	.61***	.64***	.80***	.66***	.80***				
VOC	.31*	.22	.22	.19	.47***	.40**	.44***	.54***	.62***	.71***	.70***	.67***			
RC	.25	.35**	.34**	.40**	.44***	.46***	.51***	.62***	.58***	.66***	.68***	.61***	.77***		
MACOMPU	.20	.23	.26*	.28*	.36**	.42***	.42***	.33***	.51***	.62***	.67***	.54***	.77***	.72***	

*	<.05	VIS	Visual	L	Letters	C	Confusable	S	Suppressed	VOC	Vocabulary
**	<.01	AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed	RC	Reading Comprehension
***	<.001									MATH2	Math Computation

tasks with the Auditory Intramodal task (AA) (range = .51 [$p < .05$)] to .81 [$p < .001$)] (.63 and .52 respectively). For Group 2, the only correlation which is relatively high in comparison with the rest is between AV and AA, ($r = .61$; df = 20; $p < .001$). Three other correlations reached statistical significance (range = .26 [$p < .05$] to .33 [$p < .05$]).

It is interesting to note that all correlations of VV with the other Intramodal and Crossmodal tasks failed to reach significance for all Groups (See Tables 7, 8 & 9). Also, relatively few of the correlations of VV with the other tasks reached statistical significance for any of the Groups.

With Group 1, the other Intramodal and Crossmodal tasks correlated moderately well in comparison with the IMVV correlations for the Letter and Dactylic tasks. For Group 2, on the IMAA, and CMVA and CMAV tasks, only seven of the twenty-four correlations between these and the Letter and Dactylic reached significance, and these were low (range = .30 [$p< .05$] to .47 [$p < .05$]). Only one of the correlations of VV with these tasks reached significance. For the Total Group, VA reached significance with three of the Dactylic measures and only one of the Phonetic measures; AV reached statistical significance with all of the eight Graphemic and Dactylic measures; and AA reached statistical significance with six of the eight Letter and Dactylic tasks.

It is interesting that the Intramodal and Crossmodal tasks did not correlate significantly with many of the Academic measures. Those correlations that reached significance are quite low (range .25 to .51). For example for both Group 1 and Group 2: AA with RC ($\underline{r}$ = .36, $\underline{df}$ = 20, $\underline{P}$ <.05). The strongest correlation is between VA and RC for Group 1 ($\underline{r}$ = .51, df = 20, $\underline{p}$ <.01). The mean Reading Comprehension level for this group is at the grade 5.15 grade level (Table 3). For Group 1, the second crossmodal task, AV, failed to reach a significant correlation level with RC. Overall, these results are in direct contrast with Jarman's (1975, 1979) findings with normal subjects, which indicate a high relationship between mastery on Crossmodal tasks and proficiency in reading.

Is Crossmodal proficiency, as measured by the CMVA and CMAV tasks, a necessary skill for deaf readers to master prior to developing proficiency in reading ? In order to examine this question further, subjects from Group 1 were identified who successfully completed both of the Crossmodal tasks (18 out of 26 or higher [Range of scores = 76.9 to 100 %]). Each successful Crossmodal processor was paired with another subject from the same group who failed to reach criterion on either of the Crossmodal tasks (Range of Scores = 46.0% to 73.0%).

Subjects in each pair were matched for age, degree of hearing loss and cause of deafness. More specifically, members of each pair differed in age by no more than 6 months. Hearing loss in the better ear differed by 10 dB or less. Cause of deafness was the same for the members of each pair. Seven (7) pairs were identified. Reading Comprehension (RC) scores achieved by the members of each pair were compared. The average Reading Comprehension score for the former ability group was 5.3 years while for the latter it was 4.9 years, a difference of only 6 months in reading ability. This minor difference in measured reading competence is within the Standard Error of Measurement of the test (Jensema, 1972) and is therefore an insufficient difference to use in support of Jarman's theory with this group.

Further correlations were carried out to investigate the relationship between **age** with respect to performance on the Intramodal and Crossmodal tasks, Phonetic Confusable - NonConfusable tasks and Academic tasks for Group 1, Group 2 and the Total Group (Table 10, 11 and 12 respectively). Further correlations were also carried out separately, investigating the relationship between **hearing loss** in the better ear and performance on these same tasks. Subjects performance on the Jarman and Shankweiler-derived tasks served as the independent variables while (1) **age** and (2) degree of **hearing loss** in the better ear served as the dependent variables. The present section will focus on the Intramodal

TABLE 10

Correlation Tables for Jarman, Shankweiler and Academic Tasks with Age and Hearing Loss (Group 1) (Older Group)

	VIS VIS	VIS AUD	AUD VIS	AUD AUD	LC NS	LNC NS	LC S	LNC S	DC NS	DNC NS	DC S	DNC S	VOC	RC	MA COMPU
AGE	.23	.33	.12	.20	.20	.27	.28	.41••	.33	.55•	.56•	.34••	.54•	.41••	.69••
LOSS	-.13	-.64•	-.33	-.53•	-.03	-.26	-.15	-.36••	-.25	-.19	-.23	-.08	-.26	-.31	-.20

•• <.05 • <.01 ••• <.001

TABLE 11

Correlation Tables for Jarman, Shankweiler and Academic Tasks with Age and Hearing Loss (Group 2) (Younger Group)

	VIS VIS	VIS AUD	AUD VIS	AUD AUD	LC NS	LNC NS	LC S	LNC S	DC NS	DNC NS	DC S	DNC S	VOC	RC	MA COMPU
AGE	-.08	-.16	.32	.14	.20	.31	.26	.49•	.34	.40••	.35••	.30	.22	.37••	.14
LOSS	-.24	-.42•	-.48•	-.66••	-.07	-.15	-.11	-.06	-.04	-.09	-.05	-.04	-.25	-.24	-.07

•• <.05 • <.01 ••• <.001

TABLE 12

Correlation Tables for Jarman, Shankweiler and Academic Tasks with Age and Hearing Loss (Total Group)

	VIS VIS	VIS AUD	AUD VIS	AUD AUD	LC NS	LNC NS	LC S	LNC S	DC NS	DNC NS	DC S	DNC S	VOC	RC	MA COMPU
AGE	.14	.47•••	.40••	.33	.27••	.24••	.11	.24••	.31••	.33••	.29••	.34••	.29••	.38•••	.45•••
LOSS	-.20	-.50•••	-.42••	-.60•••	-.08	-.23	-.13	-.21	-.19	-.17	.16	-.09	-.27••	-.30••	-.18

•• <.05 • <.01 ••• <.001

and Crossmodal tasks in relation to the academic measures, with discussion of the Phonetic tasks in relationship to the Academic measures occuring in another section of this chapter.

The results indicate that the total strength of association between age and the Intramodal and Crossmodal tasks is non-significant for Group 1 and Group 2 (Range = -.08 to .33). However, the correlation matrix for the Total Group indicates a moderately strong interaction between these variables, with the exception of the VV task which failed to reach significance. These results may be attributed to the larger group membership and the greater range of scores.

Earlier in this section, the performance of the Older subjects (Group 1) and Younger subjects (Group 2) was presented (Tables 3 & 4). In examining the abilities of Group 1 and Group 2 on the CMIM tasks, it appeared that ability on these measures improved with age. However, based on the present results, when the ability of all subjects on the CMIM tasks was correlated with degree of hearing loss in the better ear, the first conclusion must be re-examined. The correlations for degree of Hearing loss in the better ear with the Jarman measures, with the exception of VV, are all significant and moderate in strength for Group 1, Group 2 and the Total Group with the exception of AV for Group 1. It must be noted that all correlations between degree of Hearing loss in the better ear and the Jarman tasks are negative, indicating that degree of deafness is directly related to performance on these measures.

Stated differently, this result reveals that the greater the degree of hearing loss, the more poorly subjects performed on the CMIM tasks. This trend suggests that Jarman's tasks may not be appropriate to utilize in assessing Intramodal and Crossmodal ability in students who are profoundly deaf. However, this conclusion should be further investigated with a larger sample and include groups who have been educated using a Total Communication and an Oral methodology to determine if this result is consistent with a larger sample and for deaf individuals regardless of educational background.

In order to determine whether differences could be discerned between high and low achievers, and their performance on the Crossmodal and Intramodal, and Phonetically Confusable and Non-Confusable tasks, a discriminant function analysis was carried out.

> The general principle in Discriminant Function Analysis is that different scores of measures will be weighted in such a way as to maximize the difference between the means of two composites derived from two criterion groups, relative to the variance within these groups (Guilford, 1965, p. 434).

In conducting the Discriminant Function Analyses, three subgroups of subjects were selected separately from Group 1 and Group 2 based on their individual grade score performance on Math, Reading Comprehension, and both Math and Reading Comprehension (Overall Academics). Discriminant Function Analyses were conducted separately for each of the six subgroups. Each subject was matched with another subject from the same group, such that each subgroup was of an even number of subjects. A 'proficient performer' was paired with a 'non-proficient performer' from the same age group. For the members of each pair, cause of hearing loss was the same, age difference was less than one year, and difference in degree of deafness was less than 10 decibels in the better ear. Proficient performers scored one Standard Deviation above the group mean on the academic achievement area under investigation, while the matched non-proficient performer scored one Standard Deviation below the mean on the same subtest. The Jarman and Shankweiler-derived tasks served as the dependent variables while Academic Proficiency was the independent variable.

Results are presented in Table 13 (Older Math), Table 14 (Older Reading Comprehension), Table 15 (Older Overall Academics), Table 16 (Younger Math), Table 17 (Younger Reading Comprehension) and Table 18 (Younger Overall Academics). The

TABLE 13

Discriminant Function Analysis by Specific Group Membership with Jarman and Shankweiler Derived Tasks
(N = 18)

GROUP	TASK	DISC FUNC COEF	EIGENVALUE	CHI-SQUARE	DF	SIGNIF
OLDER PROFICIENT/ NON-PROFICIENT PERFORMERS — MACOMPU	VIS/VIS	.55925				
	VIS/AUD	.86801				
	AUD/VIS	-.77225				
	AUD/AUD	.56823				
	AGE	.37735	.22251	2.7122	5	.7443
	LCNS	-.95753				
	LNCNS	.46116				
	LCS	.01840				
	LNSC	.66066				
	AGE	.49549	.16693	2.0410	5	.8374
	DCNS	-.63770				
	DNCNS	.02354				
	DCS	.72043				
	DNCS	.86531				
	AGE	-.06577	.75801	7.6165	5	.1787

VIS	Visual	L	Letter	C	Confusable	S	Suppressed
AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed
AGE	Age in Months						

TABLE 14

Discriminant Function Analysis by Specific Group Membership with Jarman and Shankweiler Derived Tasks

(N = 12)

GROUP	TASK	DISC FUNC COEF	EIGENVALUE	CHI-SQUARE	DF	SIGNIF
OLDER PROFICIENT/ NON-PROFICIENT PERFORMERS — LANGUAGE	VIS/VIS	1.99580				
	VIS/AUD	.71081				
	AUD/VIS	- .44982				
	AUD/AUD	- .19500				
	AGE	.26033	.10728	1.3504	5	.9297
	LCNS	.02399				
	LNCNS	-1.58590				
	LCS	.50935				
	LNSC	.59321				
	AGE	.58670	1.01451	5.2528	5	.3858
	DCNS	-1.51626				
	DNCNS	1.31739				
	DCS	1.14711				
	DNCS	- .17241				
	AGE	- .22653	1.03181	6.2572	5	.2820

VIS	Visual	L	Letter	C	Confusable	S	Suppressed
AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed
AGE	Age in Months						

TABLE 15

Discriminant Function Analysis by Specific Group Membership with Jarman and Shankweiler Derived Tasks (N = 10)

GROUP	TASK	DISC FUNC COEF	EIGENVALUE	CHI-SQUARE	DF	SIGNIF
OLDER PROFICIENT/ NON-PROFICIENT PERFORMERS — OVERALL ACADEMIC	VIS/VIS	1.38916				
	VIS/AUD	1.48424				
	AUD/VIS	.22258				
	AUD/AUD	-1.05911				
	AGE	- .00474	.39691	1.8384	5	.8710
	LCNS	- .49021				
	LNCNS	.00400				
	LCS	1.82407				
	LNSC	-1.44789				
	AGE	1.27261	2.44841	6.8085	5	.2353
	DCNS	-1.17317				
	DNCNS	2.09305				
	DCS	1.07866				
	DNCS	-1.37738				
	AGE	- .32176	2.68485	7.1733	5	.2081

VIS	Visual	L	Letter	C	Confusable	S	Suppressed
AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed
AGE	Age in Months						

TABLE 16

Discriminant Function Analysis by Specific Group Membership with Jarman and Shankweiler Derived Tasks

(N = 14)

GROUP	TASK	DISC FUNC COEF	EIGENVALUE	CHI-SQUARE	DF	SIGNIF
YOUNGER PROFICIENT/ NON-PROFICIENT PERFORMERS — MACOMPU	VIS/VIS	.88582				
	VIS/AUD	-.85822				
	AUD/VIS	.13570				
	AUD/AUD	.12467				
	AGE	- .11725	.11880	1.0665	5	.9570
	LCNS	.67535				
	LNCNS	.62148				
	LCS	- .13995				
	LNSC	- .17410				
	AGE	.19716	.74812	5.3060	5	.3797
	DCNS	- .17936				
	DNCNS	-1.06751				
	DCS	- .05794				
	DNCS	.25556				
	AGE	- .20028	1.76596	9.6652	5	.0853

VIS	Visual	L	Letter	C	Confusable	S	Suppressed
AUD	Auditory	D	Dactylic	NC	Non Confusable	NS	Non Suppressed
AGE	Age in Months						

TABLE 17

Discriminant Function Analysis by Specific Group Membership with Jarman and Shankweiler Derived Tasks (N = 14)

GROUP	TASK	DISC FUNC COEF	EIGENVALUE	CHI-SQUARE	DF	SIGNIF
YOUNGER PROFICIENT/ NON-PROFICIENT PERFORMERS — LANGUAGE	VIS/VIS	.54315				
	VIS/AUD	- .22017				
	AUD/VIS	1.26307				
	AUD/AUD	- .71917				
	AGE	.22530	.22423	1.9220	5	.8598
	LCNS	.41847				
	LNCNS	1.28406				
	LCS	.17897				
	LNSC	-1.22938				
	AGE	.80331	.78728	5.5166	5	.3561
	DCNS	- .53601				
	DNCNS	1.07807				
	DCS	.15335				
	DNCS	.42031				
	AGE	- .12976	1.88307	10.0592	5	.0736

VIS Visual
AUD Auditory
AGE Age in Months

L Letter
D Dactylic

C Confusable
NC Non Confusable

S Suppressed
NS Non Suppressed

TABLE 18

Discriminant Function Analysis by Specific Group Membership with Jarman and Shankweiler Derived Tasks

(N = 12)

GROUP	TASK	DISC FUNC COEF	EIGENVALUE	CHI-SQUARE	DF	SIGNIF
YOUNGER PROFICIENT/ NON-PROFICIENT PERFORMERS — OVERALL ACADEMIC	VIS/VIS	.58288				
	VIS/AUD	- .20116				
	AUD/VIS	.84962				
	AUD/AUD	- .70074				
	AGE	- .16313	.31756	2.0684	5	.8396
	LCNS	.63346				
	LNCNS	.83315				
	LCS	.46538				
	LNSC	- .18292				
	AGE	.64874	1.23218	6.0223	5	.3041
	DCNS	- .10653				
	DNCNS	1.29944				
	DCS	2.10301				
	DNCS	-2.39834				
	AGE	.37331	5.28629	13.788	5	.0170

VIS Visual
AUD Auditory
AGE Age in Months

L Letter
D Dactylic

C Confusable
NC Non Confusable

S Suppressed
NS Non Suppressed

Intramodal and Crossmodal tasks failed to approach significant discrimination levels for any of the Older or Younger groups of proficient and nonproficient achievers (Range = -1.05911 to 1.99580). These results provide additional evidence suggesting that, with a profoundly deaf sample, the Intramodal and Crossmodal tasks failed to discriminate between good and poor achievers. It also provides additional credence to the previously stated hypothesis that the Jarman tasks may not be appropriate for determining Intramodal and Crossmodal abilities with a profoundly Deaf students.

The Intramodal and Crossmodal tasks fail to discriminate between the proficient and nonproficient academic performers. In fact, statistical analyses suggest these tasks may not be appropriate for use with a severely to profoundly deaf students. Therefore, no support could be found for Hypothesis II.

Spatial Temporal Tasks

HYPOTHESIS III states:

> Temporal and Temporal-Spatial processors will demonstrate greater proficiency in processing information in a Crossmodal manner, while Spatial processors will demonstrate greater proficiency in processing information in an Intramodal manner.

HYPOTHESIS IV states:

> Temporal and Temporal-Spatial processors will exhibit greater proficiency in academic performance than will Spatial processors.

Spatial-Temporal ability was measured using a computer-based task developed specifically for this study. The distribution of subjects in each group by Method of Processing (Temporal, Spatial, Temporal/Spatial, and Random) are listed in Table 6 (see Page 90). As can be seen from this Table, the great majority of subjects were Spatial Processors (73.0%). These cases were fairly evenly divided between the two Groups, as were the Temporal-Spatial, and Random Processors.

The nine subjects who processed information in a Temporal and Temporal-Spatial manner were also proficient in both of the

Crossmodal tasks (AV and VA). However the mean scores obtained by the Temporal and Temporal-Spatial processors on the Crossmodal tasks (VA $\underline{M}$ = 21.83; AV $\underline{M}$ = 19.33) were not significantly different from the overall group mean for these same tasks (VA $\underline{M}$ = 20.55; AV $\underline{M}$ = 18.55). ANOVA'S failed to reach significant levels of discrimination for either measure. In addition, the mean scores for the Spatial processors on the Intramodal tasks (VV $\underline{M}$ = 24.48; AA $\underline{M}$ = 16.83) were not significantly different from the overall group means for the same tasks (VV $\underline{M}$ = 24.48; AA $\underline{M}$ = 16.70). Again, ANOVA'S failed to reach significance. Therefore, no support could be found for Hypothesis III.

In reference to Hypothesis IV, to determine whether any discernible pattern could be established relative to the academic abilities of the Temporal and Temporal-Spatial processors, holding age, degree of hearing loss in the better ear, and cause of deafness constant, each Temporal (T) and Temporal-Spatial (TS) processor was matched with another subject such that each matched pair also contained a Spatial (S) processor ($\underline{N}$ = 12). Subjects were compared for their performance on the academic measures of Vocabulary (Voc), Reading Comprehension (RC) and Mathematical Computation (MaCompu). A comparison of mean grade levels of academic performance for the two groups, **T** and **TS** (Temporal and Temporal-Spatial) with **S** Spatial are presented in Table 19.

TABLE 19

Academic Performance of Subjects by Method of Processing

	ACADEMIC ACHIEVEMENT AREA		
METHOD OF PROCESSING	Voc M	RC M	MaCompu M
T & TS	4.7	5.8	8.6
S	3.2	5.6	8.7
Mean Difference	1.5	0.2	0.1

T Temporal TS Temporal-Spatial S Spatial

As can be seen from Table 19, the Temporal and Temporal-Spatial processors did not outperform their Spatial counterparts. More specifically, the mean score for the Temporal and Temporal-Spatial processors on Voc (M = 4.7), RC (M = 5.8) and MaCompu (M = 8.6) did not differ significantly from the performance of the Matched Spatial processor on the same academic measure. In fact, the differences between their mean grade scores were far less than the Standard Error of Measurement (SEM) for each subtest (Jensema, 1978). Therefore, no support could be found for Hypothesis IV.

Phonetically Confusable and Non-Confusable Tasks

Hypothesis V states:

> Good readers will demonstrate significantly more errors on phonetically confusable (rhyming) tasks than on phonetically non-confusable (non-rhyming) tasks, both dactylic and graphemic. This will be consistent for both age groups.

Hypothesis VI states:

> Poor readers will demonstrate no significant difference in number of errors on phonetically confusable and non-confusable letter tasks, both dactylic and graphemic. This will be consistent for both age groups.

Modifications of tasks developed by Shankweiler and

Liberman (1979) and Bisanz, Das and Mancini (1984) were used to test these hypotheses. The intercorrelation matrices for the Phonetic Confusable and Non-Confusable tasks are presented in Table 6, Table 7 and Table 8 for Group 1, Group 2 and the Total Group, respectively. The present section focuses on the data relative to the Phonetic tasks and their relationship to the Academic tasks, with discussion of the Crossmodal and Intramodal data presented in another section of this chapter.

As can be seen from Tables 7, 8 and 9 (See Pages 93, 94 & 95), the intercorrelations for each of the two Groups and the Total Group among the Letter/Dactylic tasks were significant. The overall pattern for these results suggests that the Letter/Dactylic tasks as a whole correlate highly with each other. Overall, the Letter and Dactylic tasks correlate with the three Academic measures, although the relationship between the Letter/Dactylic tasks with academics is stronger with the younger students (Group 2).

For the younger students, both the Letter and Dactylic tasks correlated with the academic dependent measures. However, with the older students, only one set of the dependent measures, the Dactylic tasks, correlated with the academic tasks. An examination of the performance of the two groups reveals relatively similar performance for both groups on the academic tasks.

The strength of the relationship between the Letter tasks and academic performance for the older students appears to indicate that these students rely more on dactylic information at this age and less on graphically presented information. This could be due to the nature of the academic environment where lecture format and discussion, both in sign language, predominate. With an increased reliance on the motoric component of language, and the automatized nature of the dactylic code for this population, it appears that the letter and verbal code of language becomes tertiary in nature and application.

In order to investigate the relationship between Hearing Loss and performance on the Intramodal and Crossmodal tasks, Phonetically Confusable and Non-Confusable tasks and Academic measures, and Age with respect to these same measures, further correlations were carried out for Group 1, Group 2 and the Total Group (Table 10, 11 and 12 respectively) (See Page 99). The present section will focus on the relationship between the Phonetically Confusable and Non-Confusable tasks with the academic measures. Discussion of the Intramodal and Crossmodal tasks with academic measures has occurred in another section of this chapter.

As can be seen from tables 10 and 11, the correlation matrices for degree of **Hearing Loss** in the better ear, and the Graphemic and Dactylic tasks reveal no significant correlations for Group 2 or the Total Group and only one significant correlation evident between Hearing Loss and Graphemes (.36) for Group 1 (Table 10). This one significant correlation was small in magnitude and may be by chance alone. The correlations between **hearing loss** and the Dactylic tasks for Group 1, Group 2 and the Total Group are all non-significant (Range = -.04 to -.23).

Overall, these results indicate the relationship between the degree of hearing loss and the graphemic and dactylic tasks is, at best, weak for this population. These findings suggest this population may not use a phonetic code to process visually presented information.

The use of a sign-based rather than a speech-based code by the deaf to enhance recall is reported elsewhere in the literature (Bellugi, Klima, & Siple, 1975; Hanson, 1982; Wallace & Corballis, 1973). The lack of statistical significance between performance on the Suppressed and Non-Suppressed Letter and Dactylic tasks may provide further credence to support the premise that a phonetic code is not being used.

In order to explore this possibility in greater depth, data on error type were examined with number of errors for both younger and older groups collapsed across error type. Utilizing the Confusability factor as the dependent variable, an ANOVA revealed a significant difference between similar errors in the

Confusable letter strings and nonsimilar errors in the Non-Confusable letter strings ($F = 25.78$; $\underline{df} = 1,42$; $\underline{p} < .001$). The presence of more phonetic errors in comparison with non-phonetic errors, may in fact, suggest the use of a phonetic code.

This result appears to contradict the previous finding that a phonetic code is not utilized. However, the significance of confusability only became evident when results for both older and younger groups and both Graphemic and Dactylic tasks were collapsed together and error type became the dependent variable. This finding would indicate that a phonological code is available for use, but very subtly available and not consistently enough used to benefit recall.

Croft (1990) have postulated that motivation to select an appropriate strategy may be lacking in some individuals in certain situations. That is, although strategies may in fact be available within deaf subjects' repetoire, they may not be adequately motivated to use them. Further, Croft theorized that the metacognitive processes necessary to appropriately select and execute a program of strategies for successful task completion may also be lacking.

This may in fact be occurring with the present sample, where a phonological code appears to be used intermittently. Deaf subjects in the present study were also noted to sporadically use fingerspelling rehearsal, although this strategy was not consistently utilized to aid recall. As earlier noted, Bisanz, Das, and Mancini (1984) found that, although phonological encoding of language is important for reading, the use of rehearsal strategies also seems to be an important factor underlying reading competence. Martin (1985) and Craig and Gordon (1990) reported deaf high school and college students to achieve higher reading scores after learning specific cognitive strategies for task approach.

The deaf subjects in the present study appeared unaware or unsure of the benefits of using strategies within their repetoire to aid recall. This lack of strategy use could significantly impede learning across a variety of areas. Hanson (1982) delineated three levels of reading competency for deaf subjects she studied, the best of whom used a phonetic code and were measured to be good readers. The second "intermediate" level readers intermittently utilized phonological coding and in addition, Hanson (1982) theorized that this group employed a sign or fingerspelling based code. Her poorest readers were unable to efficiently use any of these coding methods. Lillo-Martin, Hanson, and Smith (1990) found that although their better readers were able to use phonological coding, they were also assumed to take advantage of another, perhaps a sign or fingerspelling, based code.

Hanson (1982) reported that her deaf subjects, unless otherwise instructed to do so, did not encode written words into a sign-based code to benefit recall, even though this strategy was available to them. It appears that for students in the present study, although a phonological code was available, this code was not used consistently enough to be of benefit.

In examining the correlations between **age** and the Shankweiler-derived tasks, the results indicate that the total strength of the relationship between **Age** and the Graphemic tasks is very weak for all three Groups. In fact, for these groups, the correlation matrix indicates only one significant correlation for each of Group 1 (Table 9 [Age with LNCS: $\underline{r}$ = .41]) and for Group 2 (Table 10 [Age with LNCS: $\underline{r}$ = .49]). Overall, results of correlational analyses indicate a weak relationship between performance on the letter tasks and age.

As can be seen from Tables 10 and 11, age correlates significantly with three of the four Dactylic tasks for Group 1 and with two for Group 2. For the Total Group (See Table 12), all Dactylic tasks correlate significantly with age. It must be emphasized that all correlations range from low to moderately high (Range = .29 to .34).

The significance of the correlations between the reported Dactylic tasks for Group 1 and Group 2, and for all Dactylic tasks with Age for the Total Group is of interest. These findings may be directly related to the nature of the dactylic stimulus which, for this sample may provide additional information beyond that available through the letter sequences. The deaf use fingerspelling consistently for communication purposes. Therefore the Dactylic task may more closely parallel an automatized skill than does the Graphemic task.

In order to determine which of the Crossmodal and Intramodal, and Phonetically Confusable and Non-Confusable tasks acted as the best discriminator between good and poor academic performers, a Discriminant Function Analysis was carried out. The Jarman and Shankweiler-derived tasks served as the dependent variables while Academic Profeciency was the independent variable.

As can be seen from Table 17 (See Page 108), it is possible to differentiate between the Young Overall Good Achievers and Young Overall Poor Achievers (Eigenvalue = 5.29, Chi Square = 13.79; df = 5; $p <.01$) based on their performance on the Dactylic tasks, with Dactylic Confusable Suppressed (Discriminant Function Coefficient = 2.10) and Dactylic Non-Confusable Suppressed (Discriminant Function Coefficient = -2.40) contributing the highest discriminating power. It must be noted from Tables 16 and 17 that the results for the two younger groups, Good and Poor Math and Good and Poor Reading Comprehension approach significance on the Dactylic tasks ($p. = .08$ and $p. = .07$ respectively).

However, the Graphemic tasks fail to approach significant discrimination levels for any of the older or younger groups of proficient and nonproficient achievers. It seems that the discriminating power of the Dactylic task rests only with the younger age group as significance was only achieved for one young group (Overall Academics) (Table 18; See Page 108), while significance was approached for the other young groups (Reading Comprehension [RC] and Math Computation [MaCompu]). Similar results were not found for any of the older three groups (Tables 13, 14 and 15; See Pages 103, 104 & 105).

Based on these results, Hypotheses V and VI are only partially supported as the task on which the students could be differentiated for their academic proficiency was not the Confusability variable as measured by the number of errors, but the Suppression variable. In addition, this was only significant for the Younger Overall Good Achievers and not for their Older counterparts. Therefore, total support was not found for Hypothesis V and Hypothesis VI.

Additional analysis

Cluster Analysis of Subgroups by Learning Ability Measures

Overall, the performance of the two separate age groups (Group 1 and Group 2) did not significantly differ from one another across the variables. Therefore, the two groups were collapsed together to determine whether the Total Group could be separated based on their performance across the Intramodal/ Crossmodal tasks and the Shankweiler derived tasks. In order to make this determination, a Cluster Analysis was carried out. Performance on the Jarman and Shankweiler derived tasks served as the Independent Variables while Cluster Membership became the Dependent Variable.

Scores for twelve of the learning ability measures (the two intramodal and two crossmodal tasks and the eight phonetically confusable and non-confusable tasks) were transformed to weighted scores and submitted to Cluster Analysis (Hartigan, 1983) . This was followed by a hierarchical clustering procedure which began with each subject representing a cluster and then combining clusters until all subjects were in one cluster. At each step, the decision to combine clusters was based on the size of the error sums of squares which represented the difference between a subject and the centroid of his/her cluster. Clusters resulting in the least increase in the error sums of squares were combined. To determine the number of clusters which provided the best solution, the error sums of squares were examined at each step in the hierarchial clustering. Where the error sums of squares increased or "jumped" such that the increase was out of proportion with previous "jumps", it was an indication the additional cluster had created a heterogeneous cluster with extensive variance. Thus, the clusters created prior to the "jump" were examined.

When applied to the 12 learning ability measures, hierarchical clustering showed an increase in error sums of squares from three to four clusters. Therefore, the three cluster solution was selected. This division of the Total Group into three clusters (Figure 1) produced relatively distinct divisions. The three clusters included 9, 22 and 13 subjects respectively. Cluster 1 contained those subjects whose overall performance on both the Jarman and Shankweiler derived tasks was highest, Cluster 3 contained those whose performance was the lowest on these measures, while the performance of those in Cluster 2 fell between the first and second cluster (Figure 2).

With Age acting as the Dependent Variable and Cluster as the Independent Variable, an ANOVA was carried out to determine whether the Clusters differed with respect to age. A significant age difference was found between Cluster 1 and Cluster 3 ($\underline{SS} = 4546.33$; $\underline{F} = 4.63$; $\underline{df} = 2$; $\underline{p} < .05$) with those in Cluster 1

SCATTERGRAM OF CLUSTER 1, CLUSTER 2, AND CLUSTER 3

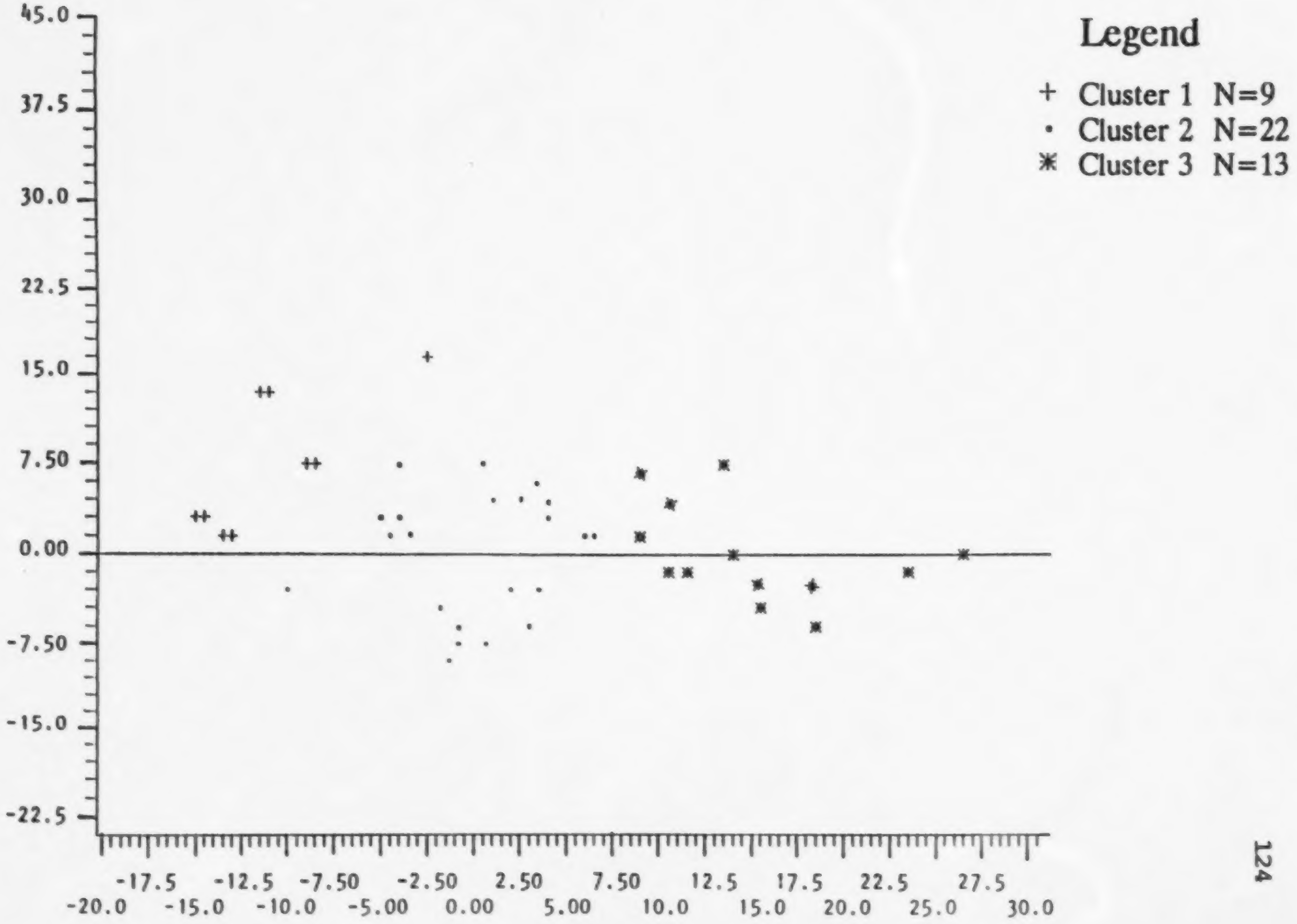

FIGURE 1

Cluster 1 — High Performers on Jarman & Shankweiler derived tasks
Cluster 2 — Mid Performers on Jarman & Shankweiler derived tasks
Cluster 3 — Low Performers on Jarmer & Shankweiler derived tasks

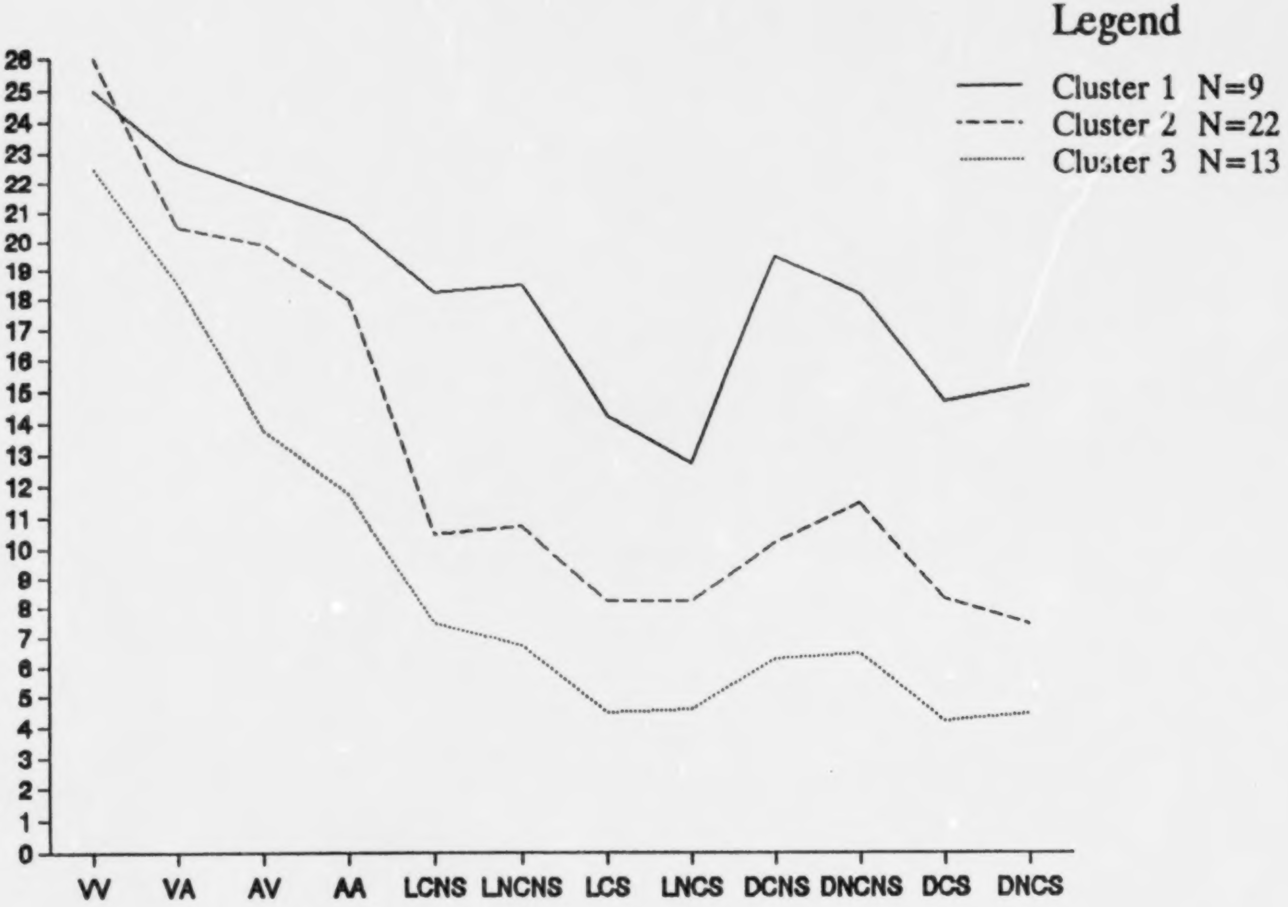

FIGURE 2

Mean Performance Scores Achieved by Cluster Members
on Crossmodal and Intramodal
and Phonetic Confusable and Non-Confusable Tasks

being significantly older than those in Cluster 3.

With hearing loss in the better ear as the Dependent Variable and again using Cluster as the Independent Variable, an ANOVA again reached significance between Cluster 1 and Cluster 3 (SS = 813.87; F = 4.63; df = 2, $p<.01$). Therefore the subjects in Cluster 1, in addition to being significantly older than those in Cluster 3, also have better hearing.

Multiple comparisons using SCHEFFE'S T TEST were conducted individually to determine whether those in Clusters 1, 2 and 3 differed in their performance on the Jarman, Shankweiler derived and Academic measures. As reported in Table 20, Cluster One was made up of nine students, seven of those were from Group One and two students were from Group Two. In addition, members of this cluster performed consistently better on all three academic tasks and manifested a lesser degree of hearing loss than those in the other two clusters. Table 21 reports the academic performance comparisons for the three clusters. The three clusters could be differentiated with respect to academic performance on Vocabulary, Reading Comprehension and Mathematical Computation. There were three exceptions, Cluster One and Two on Math Computation, and Cluster Two and Three on Vocabulary and Mathematics, where no significant differences could be found. More specifically, with respect to Vocabulary, Cluster One outperformed Clusters Two (SS = 143.73; F = 26.01 df - 2;

TABLE 20

Frequency Distribution of Cluster Members by Sex, Cause of Deafness and Method of Processing

	CLUSTER 1	CLUSTER 2	CLUSTER 3	TOTAL	N=
GROUP					
1	7	11	4	22	
2	2	11	9	22	44
M AGE IN MONTHS	16.80 years	15.43 years	14.40 years		
M HEARING LOSS					
L	96.66	102.81	108.30		
R	86.66	102.50	110.69		
SEX					
MALE	7	12	7	26	
FEMALE	2	10	6	18	44
CAUSE					
GENETIC	2	7	2	11	
(DEAF FAMILY)	2	1	0	3	
ACQUIRED	2	8	8	18	
UNKNOWN	4	5	3	12	44
PROCESS					
SPATIAL	4	17	11	32	
TEMPORAL	3	2	0	5	
TEMPORAL/SPATIAL	2	2	0	4	
RANDOM	0	1	2	3	44
M ACADEMIC PERFORMANCE					
VOCABULARY	5.4	2.9	1.8		
READING COMPREHENSION	6.5	4.6	3.1		
MATH COMPUTATION	9.5	7.4	6.6		

TABLE 21

T-TEST COMPARISONS OF ACADEMIC PERFORMANCE MEASURES FOR CLUSTERS 1, 2 AND 3

	SS	F	df	p
CLUSTER 1 TO 3:				
VOC	73.03	41.47	2	<.01
RC	61.43	23.43	2	<.01
MaCompu	48.20	13.64	2	<.01
CLUSTER 2 TO 3:				
VOC	70.70	6.20	2	>.05
RC	113.08	6.93	2	<.05
MaCompu	144.62	8.83	2	>.05
CLUSTER 1 TO 2:				
VOC	143.73	26.01	2	<.05
RC	174.51	8.72	2	<.05
MaCompu	192.82	1.60	2	>.05

$p = .05$) and Three ($SS = 73.03$; $F = 41.47$; $df = 2$; $p = .01$), while no significant differences were found between Clusters Two and Three. For Reading Comprehension, Cluster One significantly outperformed Clusters Two ($SS = 174.51$; $F = 8.72$; $df = 2$; $p = .05$) and Three, ($SS = 61.43$; $F = 23.45$; $df = 2$; $p = .01$), while Cluster Two significantly outperformed Cluster Three ($SS = 113.08$; $F = 6.93$; $df = 2$; $p = .05$). For Mathematical Computation, Cluster One outperformed Cluster Three ($SS = 48.20$; $F =13.943$; $df = 2$; $p = .01$).

Cluster Two students were younger than Cluster One by 1.4 years and older than Cluster Three by 1.0 years. Academically, Cluster Two significantly outperformed Cluster Three only on Reading Comprehension while they were not significantly different on Vocabulary and Mathematics. Students in Cluster One had a mean hearing loss at the lower end of the profound hearing loss range, while for Clusters Two and Three, the mean hearing loss was slightly greater.

It is interesting to note that Cluster One, who outperformed both other clusters on the crossmodal tasks (Figure 2), also demonstrated higher academic ability. More specifically, Cluster One outperformed Cluster Two by 2.6 years and Cluster Three by 3.7 years on Vocabulary, while Cluster Two demonstrated 1.1 years higher proficiency than Cluster 3 on Vocabulary. On Reading Comprehension, Cluster One outperformed Cluster Two by

1.9 years and Cluster Three by 3.4 years, while Cluster Two outperformed Cluster Three by 1.5 years. Finally, on Mathematics performance, Cluster One outperformed Cluster Two by 2.1 years, Cluster One outperformed Cluster Three by 3.0 years, and Cluster Two outperformed Cluster Three by 0.8 years.

Cluster One and Cluster Two were not significantly different on the Intramodal Visual task, but were significantly different on the Intramodal Auditory task. It seems that the Crossmodal and the Auditory Intramodal tasks differentiated the groups and may have contributed to the difference in academic performance.

Research to date has reported a developmental progression from intramodal to crossmodal processing. This shift occurs by about age seven (Jarman, 1975). Furthermore, Jarman elaborated that mastery of crossmodal processing is a prerequisite for reading proficiency. In fact, he has maintained intramodal processors will never master the reading process in terms of fluency and comprehension. Based on a comparison of the performance of those in Cluster One with those in Clusters Two and Three, it appears this may also be true for the profoundly deaf, although the numbers are too small to be decisive. This is an area which could benefit from further investigation with deaf oral and total communication-using proficient and non-proficient readers.

With respect to the Shankweiler derived tasks, a similar trend was apparent for the performance of the three clusters with Cluster One outperforming Cluster Two and likewise, Cluster Two outperforming Cluster Three on all Graphemic and Dactylic tasks. As noted earlier, the same pattern was evident with respect to Academic Performance. Performance reflected a similar pattern (almost the same scores) for both Graphemic and Dactylic tasks and similarily for both Confusable and Suppressed conditions.

As can be seen from Figure 2, there is little difference between the parallel Letter and Dactylic tasks, Confusable/NonConfusable, and Suppressed/NonSuppressed. This trend is manifested for all three Clusters and suggests that the subjects in each cluster are not using a phonetic code to represent and process visually presented information. Research with hearing good readers cited earlier (Bisanz, Das, & Mancini, 1984; Shankweiler & Liberman, 1979) suggests good readers use a phonetic code, even when the use of such a code penalizes performance.

If the present sample were using a phonetic code, one would expect a lower score to be evident under the phonetically Confusable condition (both Graphemic and Dactylic). However, performance remained similar for both methods of presentation. In addition, suppression of rehearsal did not interfere significantly with performance for all three clusters.

Regarding performance on Phonetically Confusable and NonConfusable tasks, hearing learners who use a phonetic strategy to process information have been shown to perform better on academic language tasks than those measured to have poorly developed phonetic ability (Bisanz, Das, & Mancini, 1984; Shankweiler & Liberman, 1979). In addition, research conducted with deaf learners has reported them to use a variety of strategies to assist recall, including phonetic, motoric and visual methods (Conrad, 1970a; Craig & Gordon, 1990; Hanson, 1982; 1985).

These findings may indicate that a linguistic (or at least phonetic) code may not have been utilized during visual presentation of the Shankweiler derived tasks. It may be hypothesized that a visual code was utilized such that the repetition of **Cowboy** both verbally and bimanually for the ten-second delay may not have interfered with the visual representation of the stimuli. It may also be hypothesized that when deaf subjects are presented with information, the strategy they may primarily draw on and utilize may be visual representation of information. However, the differentiation between good, average and poor academic performance may depend upon the effective and efficient representation of information through a primarily auditory or linguistic code. In fact, Cluster One students demonstrated greater proficiency on the

Auditory Intramodal task and Auditory Representation of information as manifested by their performance on both crossmodal tasks (Figure 2).

Subjective observation of those individuals comprising Cluster One has indicated the individuals in this cluster to be more active, efficient and effective users of language - verbal, Sign English and American Sign Language (ASL). Examination has also revealed those in Cluster Three to utilize less oral language and demonstrate less facility in English language structure. Their primary mode of communication is at a basic level of language usage. Members of Cluster Two demonstrate more proficient use of language and linguistic concepts than do Cluster Three. Nevertheless, this usage is not at the proficiency level of those in Cluster One.

Overall, it appears there may be a relationship between crossmodal processing, linguistic processing and academic performance. It may be that the deaf use a visual code to represent information and that the phonological or linguistic code is tertiary in nature although it may be used some of the time. Those able to utilize this code may also be able to perform better academically. However, it does not appear that proficient deaf learners are dependent on temporal processing of linguistic information as is reported to be the case for hearing proficient learners. Both proficient and non-proficient deaf subjects in the present study exhibited a preference for utilizing spatial processing with visually presented, temporally ordered material.

SUMMARY AND CONCLUSIONS

The primary purpose of the present study was to investigate the use of, and relationship between, performance on Crossmodal and Intramodal tasks, Spatial-Temporal processing, Phonetically Confusable and NonConfusable Graphemic and Dactylic tasks, and rehearsal with a deaf school age population. Previous research conducted with normal hearing and learning disabled groups, has measured a relationship between performance on the above tasks and academic performance.

The present study utilized two groups of subjects with mean ages of 17 years, 3 months and 13 years 6 months in testing the relationship between the above variables and academic performance. Throughout the literature, the deaf are measured as being two to five years or more delayed in their ability to perform academically, especially where linguistic skills are concerned (Conrad, 1979; Jensema & Trybus, 1978). Some researchers have noted the deaf to manifest cognitive and behavioral deficiencies similar to those manifested by culturally deprived individuals (Levine, 1981; Schlesinger & Meadow, 1972). Others have reported communication problems adversely affecting parental nurturing role (Quigley & Kretschmer, 1982) and causing frustration on teachers' part (Meadow, 1980). However, the reason for this significant delay, regardless of educational methodology employed, continue to elude educators and researchers.

Jarman (1975, 1979) established a relationship between successful crossmodal performance and reading ability for hearing subjects. Due to the measured language deficit of the deaf, a successful means of measuring Intramodal and Crossmodal processing with the deaf has not been available to date. When the present sample was examined as separate and combined age groups, the conclusion relative to the Jarman tasks is that they appear not to be appropriate for use with a profoundly deaf sample to measure Intramodal and Crossmodal match. The primary reason for this conclusion is the measured difficulty with those tasks utilizing the auditory modality.

With the population divided into the same age groups as noted above, the Shankweiler-derived Graphemic and Dactylic measures present a variable picture. Overall however, the Dactylic measures correlate more with academic proficiency than do the Letter tasks. As shown by the Discriminant Function Analysis, the sample utilizes rehearsal of some type to assist recall. But, the strategy employed is not solely phonetic or auditory, although a phonetic coding strategy may be used some of the time.

However, when a cluster analysis was conducted, using performance on the Jarman and Shankweiler-derived tasks as the independent variables and performance on the academic measures as the dependent variable, three distinct clusters emerged. Successful performance on both Crossmodal tasks and the Auditory Intramodal task, in combination with statistically better performance on all Graphemic and Dactylic tasks, regardless of Confusability or Suppression, correlated significantly with age, degree of hearing loss and more successful academic performance.

Conrad (1979), Locke (1971), Hanson (1985), and Myklebust (1966), have suggested the deaf may use a phonological code but may do so rather ineffectively. They further suggested the deaf may also use some other codes (visual, kinesthetic, dactylic sign and the like) that in themselves are less efficient than a phonological code.

For the sample under investigation in the present study, when divided on the basis of age, it appears that the same code was used to assist recall whether the stimulus was Graphemic or Dactylic. Although the correlations between the Dactylic tasks with all other measures are consistently higher than are the correlations between the Letter tasks and the same measures, the differences are slight. When the stimuli to be recalled were graphemes, again, based on comparison of performance of the two age groups, the amount of information available for remembering was less than when the stimulus was presented in a fingerspelled (dactylic) form. It is hypothesized that, with the Dactylic form, the stimulus provides a type of duplicate imagery where the dactylic form, while being held in (visual) memory is also transposed into another code or codes for secondary (or tertiary) memory store for later retrieval. When again examining the data available from the Cluster Analysis, it becomes apparent that dividing the sample on the basis of age in fact masks the bands of similarity of performance across Graphemic and Dactylic Shankweiler-derived tasks. Those achieving the higher scores on all tasks, regardless of Confusability or Suppression, also performed significantly better on the academic measures.

Research in the area of reading suggests that recognition of the alphabetic code becomes automatized and that, for recall, in the presence of normal hearing, this code can be transposed from visual to auditory at a fairly early age (Staats, 1968), the sound-symbol association being overlearned during the development of reading skills. For some sign-language using deaf individuals, the alphabetic script may be transposed into a visual-dactylic form rather than an auditory-phonetic one. Visual storage of auditorily coded information is more fleeting than auditory coding of the same type of information. Therefore, it would be expected that visually held information would be more susceptible to fading and distortion. In addition, with the method of presentation of the Dactylic tasks utilized in the present study, the novelty of the stimulus may have resulted in the line drawings of the consonant hand shapes providing additional information to be recalled. However, strikingly similar scores obtained for the parallel Letter and Dactylic tasks for cluster members indicated that, regardless of stimulus type, (Graphemic or Dactylic, Confusable or NonConfusable) or condition, (Suppression or NonSuppression), the same method of processing was employed.

With the Jarman tasks, the visual ability of this sample resulted in a large majority of the sample reaching ceiling on the VisualVisual (VV) Intramodal task. However, the auditory inability resultant from their hearing loss and their visual automatization of processing resulted in poorer performance on those tasks requiring the use of the auditory modality. In fact, on the Spatial-Temporal task, a small number of subjects were identified who, after completing their responses in a Temporal (Auditory) fashion, reordered their choices to appear in a Spatial (Visual) array. No subjects altered their Spatial responses to a Temporal pattern. This preference for use of a Visual as opposed to an Auditory method of processing may be an important factor which, overall, develops a reliance on, and preference for, visual processing of information.

However, the Total Group could not be separated into proficient and nonproficient performers on the basis of their preferred method of processing (Temporal or Spatial) as may be done with groups of hearing subjects. This difference has been termed a deficit (Das, 1983). It may, in fact, be a preferred difference. Jenner (1987) reported a spatial processing preference to exist with young deaf subjects and through the use of visual space, performance was enhanced. This is an area which warrants further investigation.

The results of the present study suggest that the Jarman and Shankweiler-derived tasks combined were able to discriminate **clusters** of good, average and poor academic performers. This finding may result in a better prediction than given by the actual performance level or traditional psychometric approaches. The findings of the study also indicate that those with a greater observed facility in communicative language - oral, Sign English and American Sign Language - perform better on the Jarman and Shankweiler-derived tasks. Therefore these tasks indirectly provide information with respect to linguistic proficiency. However, further study in this area using a larger sample and including students educated using both an Oral and a Total Communication approach could provide more information to this area. Similar data, collected with proficient and nonproficient **adult** deaf individuals, would also be of benefit in determining similarities and differences which exist in learning approaches between hearing and deaf groups.

In conducting the present study, this researcher expected to identify parallels between phonetic ability, crossmodal ability, skills in temporal processing and able academic performance. Although this prediction was somewhat true for those in Cluster 1, it was necessary to work backward to identify these clusters. Additionally, those in Cluster 1 also had better hearing and were older than those in the other two clusters. This point seems to simply reaffirm the old adage "The more you have, the better you'll do", and adds little to the knowledge base on the education of the deaf. However, it can be postulated that the clusters derived represent three quasi-distinct groups of deaf learners who may have rather distinct learning styles, learning needs and thus, educational program needs. It is further possible that members of the three clusters approached the tasks used in the present study quite differently.

Three factors must be considered when determining the ability, or inability, of a learner to complete a task. These are (1) the learner, (2) the task, and (3) the approach used by the learner to execute the task (Chance, 1986). A host of other catalytic factors must also be considered such as the attitude of the learner, work habits, motivation, and the like (Mulcahy, et al.; 1988). In examining the results of the present study in their relationship to these factors, limited strategy usage may have been reported as the tasks selected were inappropriate to use with deaf subjects. A body of literature is emerging which suggests a difference rather that a deficit model should be used when dealing with the deaf. However, subjects in the present study were able to succeed to varying degrees on several of the tasks presented. For example, improvement in task performance was measured by increased mean scores when Group 1 was compared with Group 2. Additionally, Cluster 1 subjects demonstrated statistically more able performance on the assessment measures and on academic measures.

Perhaps the tasks were too simplistic for the subjects, and more complex tasks would have revealed that subjects were able to use higher lever strategic behaviors, but this conclusion is doubtful. Research reported elsewhere (Mulcahy, et al., 1988) has identified the need for hierarchical development of learning skills from simple to more complex.

Subjects may have been victims of the history of deaf education, wherein deaf students have fared poorly, thus leading the subjects to a 'self-fulfilling prophesy' of poor performance. Or teachers may have taught them, holding this history to be the reality for deaf students. Or the students may have been poorly motivated in applying themselves to the tasks. These catalytic factors can effect the ability of any learner in his or her approach to a task, and although it can certainly be postulated that these factors influenced the performance of the subjects in the present study, it is doubtful that the differences in performance measured were solely due to these intrinsic factors. We are left to examine more closely the learner, and the learners' approach to the task.

Deaf individuals are frequently referred to as being a homogeneous group or a variety of homogeneous groupings: 'the deaf; 'the prelingually deaf'; 'the profoundly deaf'; 'the adult deaf'; 'the adventitiously deafened'. Any of these groups may have elastic boundaries, individuals within one group varying by degree of deafness, age of onset, age at amplification, cause of deafness, and a myriad of other characteristics. Additionally, any one person may fall within several of these groups, depending on the criteria used to determine group membership. It quickly becomes apparent that to expect great commonalities across a large number of deaf individuals is erroneous. Deaf learners should be expected to vary. Yet, results of the present study reveal a striking similarity in **inability** to perform on academic tasks. The large majority of the subjects were also unable to utilize strategic behaviors in approaching the assessment measures. This leads us naturally to the issue of task approach.

Why are the highest academic achievers of the study group able to read only at the Grade 5 level after 10+ years of schooling? Why are many of the subjects unable to capitalize on their visual strength measured by the Crossmodal-Intramodal tasks? Why do some of the subjects switch strategies, such as with the spatial-temporal task? Why is it that the deaf subjects in the present study do not use strategies to aid their recall even when such strategies are available to them, as with the phonetic coding task ? Can deaf subjects be taught to be better learners?

There is a growing body of research in the area of cognitive strategies training programs for hearing individuals (Chance, 1986; Mulcahy et al., 1988; Nickerson, 1989) and deaf individuals (Martin, 1985; 1989; Pachal, 1986). This research reports favorably on the beneficial use of such programs, primarily with post secondary aged students. However, research is needed examining the abilities of school aged deaf students and their strategic behavior. A hierarchy of questions to be addressed include:

1. Which cognitive strategies can best be taught to deaf school aged students?

2. Once learned, can such strategies be beneficially applied to enhance learning?

3. Can alternate strategies be chosen and executed to produce favorable results? If so, which ones?

4. Given a novel situation, can novel strategies be generated by the individual? If so, how?

In investigation of the first question, variations in baseline strategic abilities would be expected. The present research revealed 3 Clusters of ability levels within the study group. This number of groupings may be typical of other groups of deaf individuals. Determining what strategies students use, their knowledge about their own strategies, and their effectiveness in using their own strategies is an important first step in initiating a program of cognitive strategies training.

As stated earlier in this study, two broad classifications of causes - **global** and **specific** - have been postulated to result in the academic delay of the deaf. Although researchers (Hanson, 1985; Kusche, 1985; Liben, 1985) have suggested insufficient strategy useage as being one of the **specific** causes, to date no systematic research is reported in the literature specifically focusing on the determination of cognitive strategy usage with deaf students, the teaching of learning strategies, or the measurement of the degree to which such strategies are used and modified to enhance academic learning. The development of such a program may offer a means of assisting with the improvement of academic teaching and learning for a portion of the deaf student population. Although further research is needed, the theoretical construct and empirical evidence of this study show promise for shedding light on causal elements affecting academic performance and proposes an avenue for the improvement of learning skills for deaf individuals.

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APPENDIX A

AUDITORY-AUDITORY MATCHING TASK

SAMPLE ITEMS:

```
 1.    - - -
       - - -

 2.    - - -
       -  -  -

 3.    - -  -
       -  - -

 4.    -  -  -
       -  -  -

 5.    -  -  -
       -  - -
```

TEST ITEMS:

```
10.    -  - -  -
       -  - -  -

11.    -  -  - -
       -  - -  -

12.    - -  -  -
       - -  -  -

13.    -  -  - -
       -  -  -   -

14.    -  - - - -
       -  - - - -

15.    - -  - - -
       - -  - - -

16.    - -  - -  - -
       - -  - -  - -

17.    - - -  - -
       - - - -  -

18.    -  - - - -
       - - - -  -

19.    -  -  -  - -
       -  -  - -  -

20.    -  - -  -  -
       -  - -  -  -

21.    - -  -  -  -
       - -  -  -  -

22.    -   -   -   - -
       -   -   - -   -

23.    - - - -  -  -
       - - - -  -  -

24.    -  - -  - - -
       -  - - -  - -

25.    - -  -  - - -
       - -  - -  - -

26.    - -  -  -  - -
       - -  -  -  - -

27.    -  -  -  - - -
       -  -  - -  - -

28.    -  -  - -  -  -
       -  - -  -  -  -

29.    - -  -  -  -  -
       - -  -  -  -  -

30.    - - - -  - - -
       - - - -  - - -

31.    - - -  - -  - -
       - - -  - - -  -

32.    -  - - - -  - -
       - -  - - -  - -

33.    -  - - -  -  - -
       -  - - -  -  - -

34.    -  -  - -  -  -  -
       -  -  - -  -  -  -

35.    - -  -  - -  -  -
       -   - -  - -  -  -
```

KEY: Each - represents a TONE stimulus presented on audio tape.

APPENDIX A
VISUAL-VISUAL MATCHING TASK

SAMPLE ITEMS:

```
 1.    . . .
       . . .

 2.    . . .
       .  .  .

 3.    . .  .
       .  . .

 4.    .  .  .
       .  .  .

 5.    .  .  .
       .  . .
```

TEST ITEMS:

```
10.    .  . .  .
       .  . .  .

11.    .  .  . .
       .  . .  .

12.    . .  .  .
       . .  .  .

13.    .  .  . .
       .  .  .   .

14.    .  . . . .
       .  . . . .

15.    . .  . . .
       . .  . . .

16.    . .  . .  . .
       . .  . .  . .

17.    . . .  . .
       . . . .  .

18.    .  . . . .
       . . . .  .

19.    .  .  .  . .
       .  .  . .  .

20.    .  . .  .  .
       .  . .  .  .

21.    . .  .  .  .
       . .  .  .  .

22.    .   .   .   . .
       .   .   . .   .

23.    . . . .  .  .
       . . . .  .  .

24.    .  . .  . . .
       .  . . .  . .

25.    . .  .  . . .
       . .  . .  . .

26.    . .  .  .  . .
       . .  .  .  . .

27.    .  .  .  . . .
       .  .  . .  . .

28.    .  .  . .  .  .
       .  . .  .  .  .

29.    . .  .  .  .  .
       . .  .  .  .  .

30.    . . . .  . . .
       . . . .  . . .

31.    . . .  . .  . .
       . . .  . . .  .

32.    .  . . . .  . .
       . .  . . .  . .

33.    .  . . .  .  . .
       .  . . .  .  . .

34.    .  .  . .  .  .  .
       .  .  . .  .  .  .

35.    . .  .  . .  .  .
       .   . .  . .  .  .
```

KEY: Each - represents a TONE stimulus presented on audio tape.
Each . represents a DOT stimulus presented on visual slide.

APPENDIX A
AUDITORY-VISUAL MATCHING TASK

SAMPLE ITEMS:

```
 1.   - - -
      . . .

 2.   - - -
      .  .  .

 3.   - -  -
      .  . .

 4.   -  -  -
      .  .  .

 5.   -  -  -
      .  . .
```

TEST ITEMS:

```
10.   -  - -  -
      .  . .  .

11.   -  -  - -
      .  . .  .

12.   - -  -  -
      . .  .  .

13.   -  -  - -
      .  .  .  .

14.   -  - - - -
      .  . . . .

15.   - -  - - -
      . .  . . .

16.   - -  - -  - -
      . .  . .  . .

17.   - - -  - -
      . . . .  .

18.   -  - - - -
      . . . .  .

19.   -  -  -  - -
      .  .  . .  .

20.   -  - -  -  -
      .  . .  .  .

21.   - -  -  -  -
      . .  .  .  .

22.   -   -   -   - -
      .   .   . .   .

23.   - - - -  -  -
      . . . .  .  .

24.   -  - -  - - -
      .  . . .  . .

25.   - -  -  - - -
      . .  . .  . .

26.   - -  -  -  - -
      . .  .  .  . .

27.   -  -  -  - - -
      .  .  . .  . .

28.   -  -  - -  -  -
      .  . .  .  .  .

29.   - -  -  -  -  -
      . .  .  .  .  .

30.   - - - -  - - -
      . . . .  . . .

31.   - - -  - -  - -
      . . .  . . .  .

32.   -  - - - -  - -
      . .  . . .  . .

33.   -  - - -  -  - -
      .  . . .  .  . .

34.   -  -  - -  -  -  -
      .  .  . .  .  .  .

35.   - -  -  - -  -  -
      .   . .  . .  .  .
```

KEY: Each - represents a TONE stimulus presented on audio tape.
Each . represents a DOT stimulus presented on visual slide.

APPENDIX A
VISUAL-AUDITORY MATCHING TASK

SAMPLE ITEMS:

```
1.   . . .
     - - -

2.   . . .
     -  -  -

3.   . .  .
     -  - -

4.   .  .  .
     -  -  -

5.   .  .  .
     -  - -
```

TEST ITEMS:

```
10.  .  . .  .
     -  - -  -

11.  .  .  . .
     -  - -  -

12.  . .  .  .
     - -  -  -

13.  .  .  . .
     -  -  -   -

14.  .  . . . .
     -  - - - -

15.  . .  . . .
     - -  - - -

16.  . .  . .  . .
     - -  - -  - -

17.  . . .  . .
     - - - -  -

18.  .  . . . .
     - - - -  -

19.  .  .  .  . .
     -  -  - -  -

20.  .  . .  .  .
     -  - -  -  -

21.  . .  .  .  .
     - -  -  -  -

22.  .   .   .   . .
     -   -   - -   -

23.  . . . .  .  .
     - - - -  -  -

24.  .  . .  . . .
     -  - - -  - -

25.  . .  .  . . .
     - -  - -  - -

26.  . .  .  .  . .
     - -  -  -  - -

27.  .  .  .  . . .
     -  -  - -  - -

28.  .  .  . .  .  .
     -  - -  -  -  -

29.  . .  .  .  .  .
     - -  -  -  -  -

30.  . . . .  . . .
     - - - -  - - -

31.  . . .  . .  . .
     - - -  - - -  -

32.  .  . . . .  . .
     - -  - - -  - -

33.  .  . . .  .  . .
     -  - - -  -  - -

34.  .  .  . .  .  .  .
     -  -  - -  -  -  -

35.  . .  .  . .  .  .
     -   - -  - -  -  -
```

KEY: Each . represents a DOT stimulus presented on visual slide.
Each - represents a TONE stimulus presented on audio tape.

APPENDIX B

SET:_____A/A_____V/V_____A/V_____V/A______

TRAINING TRIALS:

1. **same** different
2. same **different**
3. same **different**
4. **same** different
5. same **different**

ASSESSMENT TRIALS

10. **same** different
11. same **different**
12. **same** different
13. same **different**
14. **same** different
15. **same** different
16. **same** different
17. same **different**
18. same **different**
19. same **different**
20. **same** different
21. **same** different
22. same **different**
23. **same** different
24. same **different**
25. same **different**
26. **same** different
27. same **different**
28. same **different**
29. **same** different
30. **same** different
31. same **different**
32. same **different**
33. **same** different
34. **same** different
35. same **different**

APPENDIX C

SPATIAL TEMPORAL NUMBER SERIES

TRAINING TRIALS:

1.	2	1	4	2.	4	7	9	3.	5	3	6
	C	B	A		A	C	B		A	B	C

TEST TRIALS:

1.	7	2	3	11.	3	5	9
	B	A	C		B	A	C
2.	2	9	7	12.	6	7	2
	A	C	B		A	C	B
3.	8	2	5	13.	5	1	3
	B	A	C		A	C	B
4.	4	7	6	14.	2	6	1
	C	B	A		B	A	C
5.	9	1	4	15.	8	5	4
	A	B	C		C	B	A
6.	3	7	2	16.	6	9	8
	C	A	B		A	C	B
7.	1	6	3	17.	5	4	7
	B	C	A		C	B	A
8.	8	5	2	18.	6	3	1
	A	C	B		A	C	B
9.	4	9	1	19.	2	1	6
	B	A	C		B	A	C
10.	1	2	6	20.	9	6	4
	A	C	B		C	B	A

APPENDIX D

Instructions for Administration of
Spatial Temporal Task

Students are administered this task individually using an Apple computer. Students are seated in front of the computer in a small office, free of distractions. The computer program is set up prior to the student entering the room.

TODAY YOU WILL SEE SOME NUMBERS ON THE COMPUTER SCREEN. THE NUMBERS ARE ALL SINGLE DIGITS. THEY WILL APPEAR AT THREE DIFFERENT PLACES ON THE SCREEN: HERE (examiner points to center left of the screen), HERE (examiner points to center of the screen), AND HERE (examiner points to center right of the screen).

AFTER YOU HAVE SEEN THE THREE NUMBERS, YOU MUST TYPE THE SAME NUMBERS INTO THE COMPUTER, AND TELL THE COMPUTER WHICH NUMBER WAS FIRST, SECOND, AND THIRD. TO TELL THE COMPUTER THE FIRST NUMBER, PRESS THE LETTER "A", THEN THE NUMBER. FOR THE SECOND NUMBER, PRESS "B", THEN THE NUMBER, AND FOR THE THIRD, PRESS "C" THEN THE THIRD NUMBER YOU SAW ON THE COMPUTER SCREEN. YOU MAY ENTER THE NUMBERS IN ANY ORDER YOU WISH. THE COMPUTER WILL ASK IF YOU WANT TO CHANGE ANY OF THE NUMBERS, OR

THE ORDER OF YOUR ANSWERS, BEFORE GOING TO THE NEXT SET OF THREE NUMBERS. LETS GO THROUGH AN EXAMPLE TOGETHER SO YOU CAN SEE WHAT I MEAN.

A sample number set is presented and reviewed with the student.

DO YOU HAVE ANY QUESTIONS?

Questions of clarification are answered. If a student ask if numbers are to be entered in a particular fashion, she/he is instructed to enter the numbers seen on the screen in the manner most comfortable to her/him.

ARE YOU READY?

When student indicates she/he is ready, the student is instructed to begin and continue to the end of the number sets.

APPENDIX E

PHONETIC SIMILAR AND DISSIMILAR DACTYLIC STRINGS

PRE-TEST SERIES ORDER : D C R B Q H L S T P W K G V

TRAINING TRIALS

1. K Q R H L	1. T C V P G	1. H R L Q K
2. C G B P D	2. K S W L H	2. V D T B C

SET 1	SET 2	SET 3
1. H L R W Q	1. G B P V T	1. Q W R L H
2. C G D P B	2. S Q L R H	2. B D P G C
3. H Q S H L	3. W S Q L R	3. L H S Q K
4. H R W K S	4. P T C B V	4. S K Q R L
5. B D G T C	5. L K S R W	5. C G T P B
6. V P T C D	6. T P B D C	6. K L H S Q
7. Q S H L K	7. D V G C P	7. D T B C V
8. T C V D G	8. R H W K L	8. G V D T P
9. D V B G P	9. V C D B T	9. Q H K W R
10. R W K H Q	10. K L H S W	10. P B C V D

APPENDIX E

PHONETIC SIMILAR AND DISSIMILAR LETTER STRINGS

PRE-TEST SERIES ORDER : D C R B Q H L S T P W K G V

TRAINING TRIALS

1. KQRHL	1. TCVPG	1. HRSQK
2. CGBPD	2. KSWLH	2. VDTBC

SET 1	SET 2	SET 3
1. SLQRK	1. CPTVG	1. QSKHW
2. DGVTP	2. SHQLK	2. VDPGB
3. GCDBV	3. VGPTB	3. HLSRQ
4. LWHKS	4. DTVCP	4. LRHWS
5. RKLQH	5. RWLKH	5. DVGBP
6. PDBGC	6. PVBDC	6. KWQLR
7. BVCDT	7. KSWHR	7. BPCVT
8 QHKLW	8. WQRSL	8. WKRQL
9. TBGPD	9. TCGBD	9. CBTPG
10. KQWSR	10. HRSWQ	10. GTDCV

APPENDIX F

Instructions for Administration of Phonetically Confuasble and NonConfusable Tasks

Students are seated in a a semi-circle and equidistant from the viewing screen. Each student is provided with a pencil and a clip board to which is attached a set of response forms.

TODAY I WILL SHOW YOU SOME LETTERS USING SLIDES. THESE ARE THE LETTERS YOU WILL SEE. PLEASE FINGERSPELL THEM AS THEY APPEAR ON THE SCREEN.

Students are shown the consonants in random order and sign each as it appears on the screen.

NOW I WILL SHOW YOU SOME LETTERS THAT YOU MUST REMEMBER. AFTER YOU SEE THEM, YOU MUST WAIT FOR TEN SECONDS (AND REPEAT COWBOY BOTH VERBALLY AND IN SIGN WITH ME), THEN WRITE DOWN AS MANY OF THE LETTERS AS YOU CAN REMEMBER. IT IS IMPORTANT THAT YOU WRITE THEM DOWN IN THE SAME ORDER AS THEY APPEAR ON THE SCREEN. IF YOU FORGET ONE OF THE LETTERS, LEAVE A BLANK SPACE ON YOUR ANSWER PAPER. ARE THERE ANY QUESTIONS?

(Questions of clarification are answered).

READY?

As soon as all students indicate they are ready, the examiner points to the screen and then activates the the timing device.

As soon as the last letter slide fades, and a blank slide is projected, the examiner holds up her hand, and simultaneously says/signs (while repeating vocally and bimanually with the students, "COWBOY", for ten seconds).

ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT, NINE, TEN. GO.

Students record the letters on the response form provided. As soon as all students have written down the letter strings recalled, and looks toward the examiner:

READY?

Each letter string is administered in the same manner.

APPENDIX G

PC/NC RESPONSE FORM

NAME:__________________________ SET:________________________

______ ______ ______ ______ ______